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Edited by

CARLETON REA and J. RAMSBOTTOM

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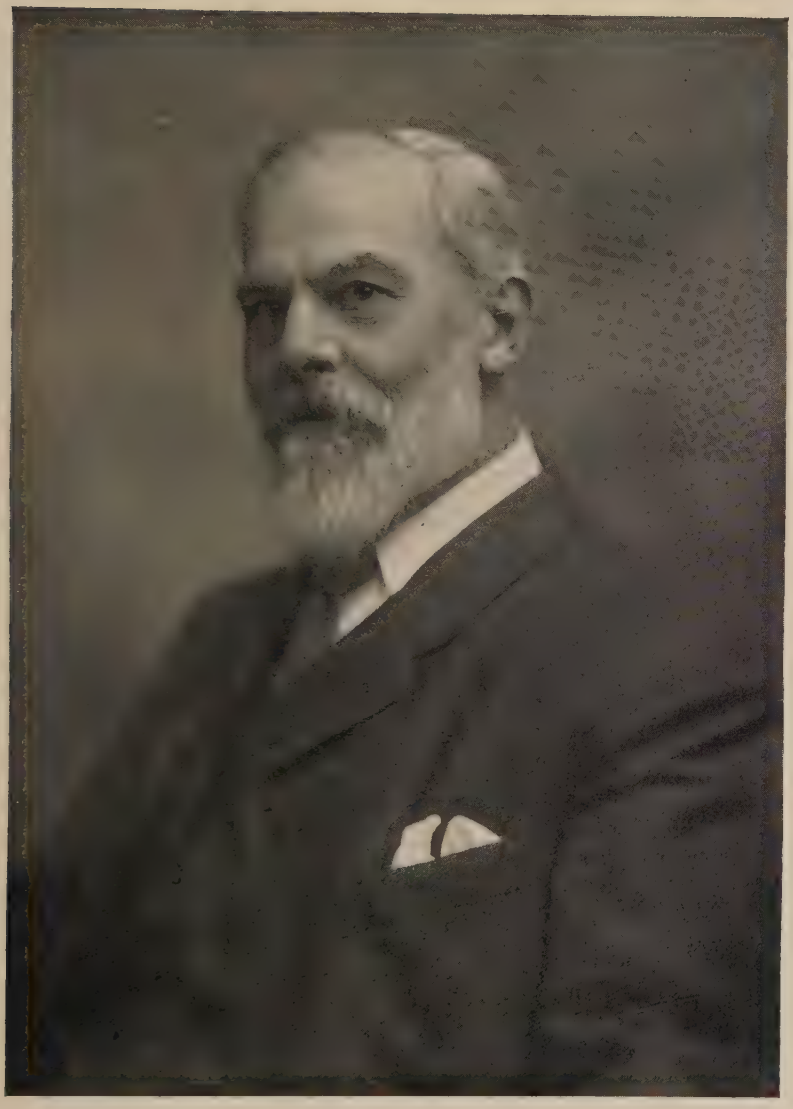


WILLIAM NORWOOD CHEESMAN

WILLIAM NORWOOD CHEESMAN.

1847–1925.

By J. Ramsbottom.

By the death of Mr W. N. Cheesman, J.P., F.L.S., our Society, for the first time in its history, had to mourn the loss of the President during his term of office. He had been ill for some months but the end, when it came, was unexpected.

William Norwood Cheesman was born at Winterton, Lincs. on Feb. 1st, 1847; as a youth he spent some time at Hull and then went to London to learn the drapery business. In his twenty-fifth year he joined his uncle at Selby in the extensive drapery establishment which later became Cheesman (Selby) Ltd. Latterly he had retired from active participation in its affairs though he retained his seat on the directorate. It was while in London that Mr Cheesman began to take an interest in nature study. The controversies which had not then died down after the publication of Darwin's *Origin of Species* no doubt gave many young men their first taste for natural history or whetted their appetites. That it may have been so in Cheesman's case also seems likely as he was proud of having known Charles Darwin whose home at Mitcham he had visited occasionally.

On going to Selby (1870) young Cheesman soon got a local reputation as a general naturalist, but particularly as a botanist. In the first volume of the new series* of the *Naturalist* (1875–6), the Journal of the West Riding Consolidated Naturalists' Societies which was formed in 1861, he is shown as Secretary of the Selby Naturalists' Society. With the joining up of local societies as the Yorkshire Naturalists' Union (1877) a comprehensive study of the natural history of the county was initiated. After the time of James Bolton's *History of Fungusses growing about Halifax* (1788–91) the study of fungi in Yorkshire had been spasmodic. Now a number of members, among whom were Dr H. F. Parsons, Rev. W. Fowler, Messrs W. West and W. N. Cheesman interested themselves in fungi as one of the "neglected orders" which were marked out for special study. A fungus foray took place in 1881 with Leeds as a centre. The next foray was held at Selby in 1884, the arrangements being made by Mr Cheesman: the account of this foray (*Naturalist*, x, p. 140, 1885) suggests that hospitality on his part was not lacking. A third foray was held in 1888 and since 1891 there has been one annually. The study of fungi in the field was increasing

* The first series was 1864–67.

in popularity in Yorkshire at a time when the Woolhope forays were declining after Dr Bull's death in 1886. A mycological committee was formed in 1892. "The justly celebrated Hereford Foray...the universally acknowledged meeting place for exchange of opinion and courteous criticism between British and foreign mycologists has unfortunately run its course, and it is the hope and ambition of the Yorkshire Union that the annual autumn gathering may—by avoiding the weak points of its predecessor, which were mainly confined to an excess of hospitality—prove at least equally attractive and instructive to mycologists"*.

At the Huddersfield foray in 1895 the idea of a National Mycological Union was discussed and at Selby the following year the British Mycological Society was formed, the arrangements being talked over in Cheesman's house, "over a cup of tea" to use his own words. Mr George Massee was elected first President and held the post for two years; then for some reason he withdrew from the Society with several of his Yorkshire friends, among whom was his great admirer Mr Cheesman. What Massee failed to realise was that the day of supreme authority had passed, even in systematic mycology, but he was willingly accorded that position in Yorkshire, continuing as chairman of the Mycological Committee until his death. When it was clear that the British Mycological Society was accomplishing the work it had set itself, matters straightened out to a great extent and at the time I joined the Society in 1910 there was no more enthusiastic member than Mr Cheesman. I met him for the first time at the Taunton foray in 1911. He acted there as he always did with beginners, taking the greatest delight in pointing out the characters of the fungi exhibited on the plates: one had only to show interest in order to receive every assistance it was in his power to give. Many mycologists on looking back at their first foray will doubtless recall that it was our late President who made it his business to give them what help he could. He did not enjoy the reputation of some of his Yorkshire colleagues as a systematist—many of them acquired European reputations—but his work did not lie in that direction. He was essentially a populariser of the subject and as a careful and energetic collector he was one of the best-known amateurs in the country. In later years he was particularly interested in Mycetozoa.

As a recognition of his efforts in furthering the study of mycology he was elected President of the Yorkshire Naturalists' Union in 1916 and took as the subject for his address *Economic Mycology: the beneficial and injurious influences of fungi*. The

* C. Crossland, *Naturalist* (1894), p. 69.

title was fully indicative of the scope of the address which was an able exposition of the importance of the study of fungi.

He was a regular attender at the British Association meetings both at home and overseas. In this country he represented our Society as delegate on several occasions: his visits further afield to Canada, South Africa, Australia and New Zealand resulted in excellent collections of fungi and Mycetozoa.

In 1918 he was elected to the newly formed Council* of our Society, served as Vice-president in 1923, and was elected President for the year 1925.

He felt that his health might prevent him from being an effective President but arrangements were made that enabled him to consent to serve. He fully appreciated the honour judging from the letters he wrote in answer to accounts he received of arrangements to be made and those carried out. It was a great trouble to him that he was not well enough to prepare a Presidential address, but it was a medical veto rather than the advice of his friends that at length persuaded him that it would be unwise to attempt one. Just before the Dublin foray he wrote to me as follows:

"I have just received the notice of our annual meeting at Dublin and I regret very much that I am not able to attend; I am still having the doctor's attention; at times I think that I am getting better at other times I think otherwise.

"Certainly I am better than I was a year ago, but am only able to walk about gently with my stick; my time is spent all day in my garden and greenhouse, when I am able to ponder over the pleasant past and the joyous reflections of happy days spent in the fields and at our Forays. I am thus able, in contentment, to pass my time smoking my pipe (four ounces a week), working crossword puzzles, solving chess problems and reading light, frivolous literature....

"I had two or three plans for my address to the members but my doctor strongly discouraged me from undertaking any serious mental work.

"Please convey to the members my hearty greetings and my grateful thanks for the great honour they did me by electing me as their President. I am now sorry that my illness has made me such a useless President.

"I hope that you will have a good time at Dublin and find plenty of interesting 'stuff.'

"My best wishes are for the continued prosperity of the Society and my hope that the membership will soon number a thousand for with increased membership the hands of the officers will thereby be strengthened in the important work they are carrying on.

* Again at Selby.

"The B.M.S. Forays have been bright periods in my life and many other members will have the same feelings.

"Again, with best wishes to all,

"I remain, Yours sincerely,

"W. N. Cheesman.

"P.S. I enclose cheque for one hundred guineas which I wish our Treasurer to invest and the proceeds applied to the printing fund or to such other purposes as the Council may decide."

This unexpected, though characteristic generosity, was greatly appreciated. After considerable discussion the Council decided that the best use of the gift would be to enable one or more students to attend the autumn forays which our President so valued. It was decided to ask him whether this would meet with his approval—but he died on November 7th, the day following the meeting.

In addition to his natural history activities Mr Cheesman studied Archaeology and was for many years a prominent member of the Yorkshire Archaeological Society. He was keenly interested in Selby Abbey and acted as churchwarden for some years. As a prominent Freemason he combined his archaeology and his craft and wrote several papers, the most important of which was *On Mason's marks in particular, and Mediaeval Craftsman's marks in general.* He was prominent in all affairs of Selby, and had served as president of a considerable number of associations connected with the town as well as being a Justice of the Peace for the West Riding. In his younger days he was a strong swimmer—he swam the Humber while at Hull —and took a great delight in all kinds of sport. It was a pleasure to be in his company as he had so many interests and, moreover, enjoyed a good story—either in the telling or in the hearing; "one of Cheesman's" used often to go the rounds of a foray. His death removes from our circle one who was sincerely respected by all. To the younger mycologists he was representative of a type that seems in danger of being swamped by the greatly increased numbers of professional workers. In these days when there are so many pleasures in which business men may obtain their necessary relaxation it should be the aim of the professional worker to encourage business-men naturalists and working-men naturalists to continue to share those of our labours and our delights that their occupation allows.

The death of William Norwood Cheesman takes from our ranks in the year in which he occupied the premier position a very fine type of English gentleman: generous, kind, earnest, and one who had the interests of his country at heart.

It is a pleasing thought that his name will ever be associated with the Society in connection with the Cheesman Fund.

THE TINTERN FORAY.

April 24th to 28th, 1925.

By E. M. Wakefield, M.A., F.L.S.

The Spring Foray was held at Tintern from April 24th to April 28th, with headquarters at the Beaufort Arms Hotel. About fifteen members assembled during the evening of the 24th, some having already been out and gathered a few species, chiefly of micro-fungi.

On Saturday morning a start was made at 10 a.m. for the woods lying north of Tintern. It was soon apparent that the larger fungi were extremely scarce, probably owing to the prevailing cold, dry winds, and that the list would have to be made up chiefly of micro-forms. Along the hedge bank of a narrow lane leading upwards behind the village were found several Rusts, including *Puccinia tumida* on *Conopodium*, *Milesina Scolopendrii* on the hart's-tongue fern, and *Milesina Polystichi* on *Polystichum angulare*. The two latter species, and also *M. Kriegeriana* on the male fern, were found in some abundance throughout the foray, and it is interesting to record that *M. Scolopendrii* and *M. Kriegeriana* had also been found to be abundant in South Devon just a week earlier. In a coppice near the top of the hill a very fine specimen of *Dermatea Cerasi* was obtained on dead branches of *Prunus Avium*.

On Sunday morning some of the members spent a short time in a wood beside the railway on the Gloucestershire side of the River Wye. This wood was very damp in the lower part, near the river, and consequently some of the larger Discomycetes were found here, which did not occur elsewhere during the foray. *Mitrophora hybrida* was soon noticed, and Miss Brett later picked up a fine specimen of *Disciotis venosa*. Both *Ciliaria scutellata* and *C. trechispora* were also found. Dead twigs, of willow and ash chiefly, yielded various Pyrenomycetes, and also *Propolis faginea*.

In the afternoon the whole party walked to Wyndcliff, obtaining on the way two interesting Discomycetes growing on the dark basal part of dead stems of *Pteris*, namely *Micropodia pteridina*, and a pale yellowish form somewhat resembling *Helotium cyathoideum*, which was subsequently identified by Mr W. D. Buckley as probably *Dasyscypha caulicola* (Fr.) Boud., about which little seems to be known. Dr Malcolm Wilson secured *Synchytrium Mercurialis* and later *S. Taraxaci*. On the descent from the Wyndcliff some very fine specimens of *Daldinia concentrica* were noted.

On Monday morning the woods on Chapel Hill were visited. The ground here was very dry and little of interest was obtained. In a small marshy spot at the bottom of the hill some dead giant Heracleums were found, whose stems were covered with fine fructifications of *Heterosphaeria Patella*, unfortunately however with the asci as yet immature. One small dead twig, unidentified, yielded a few perithecia with the characteristic spores of *Leptospora caudata* Fuck.

The party returned home for lunch and in the afternoon another visit was paid to some of the ground covered on Saturday, which so far had proved most productive, the return being made by way of Barbados Hill.

Here Miss Roper found a plant or two of *Jasione montana* showing blackish pustules on the leaves, which to the naked eye appeared like one of the Rusts. Microscopic examination showed however that the fungus resembled the early stage of certain Discomycetes. Unfortunately it was quite immature, but the species if found again may prove to be *Pyrenopeziza Jasiones* Romell, which would be a new record for this country.

Taphridium umbelliferarum occurred scantily in a hedge, and towards the end of the walk a mass of dead stems of broom yielded *Nectria sanguinea*, *N. mammoidea* and *Volutella ciliata*, all in considerable abundance. Ivy leaves which were brought back with *Phyllosticta hedericola* and *Septoria Hederae*, later produced also *Vermicularia trichella* and *Mycosphaerella hedericola*.

A short business meeting was held on the Monday evening, with Mr Pearson in the chair. The President, Mr Cheesman, sent apologies for his absence through ill-health, and best wishes for the success of the meeting. A letter was read from Dr Durham, President of the Woolhope Club, expressing a hope that the Society would find it possible to hold a foray in conjunction with the Woolhope Club, some time in the near future. As the 1925 Foray was already fixed for Dublin, and an alternative foray was considered not practicable, it was decided that the General Secretary should be asked to write to Dr Durham suggesting that the Autumn Foray in 1926 might be held at Hereford.

The locale of the next Spring Foray was also considered, and after some discussion members voted in favour of Arundel if possible, or if not some other convenient spot in the South Eastern district.

Two new members, Dr O. F. Burger of Gainesville, Florida, and Mr W. F. Hanna were elected, and the meeting closed with hearty votes of thanks to the Commissioners of Woods and Forests and to Mr Hastings Clay, for permission to work over their lands.

For assistance in compiling the subjoined list the Secretary is indebted to all the members present.

Complete List of Fungi gathered during the Foray.*

HYMENOMYCETES.

Armillaria mellea (Vahl.) Fr. (rhizomorphs only).
Omphalia Swartzii Fr.
Panus stipticus (Bull.) Fr.
Lenzites betulina (Linn.) Fr.
Entoloma clypeatum (Linn.) Fr.
Claudopus variabilis (Pers.) W. G. Sm.
Galera tenera (Schaeff.) Fr., hypnorum (Schrank) Fr.
Tubaria furfuracea (Pers.) W. G. Sm.
Hypholoma sublateritium (Schaeff.) Fr., fasciculare (Huds.) Fr.
Coprinus micaceus (Bull.) Fr.
Panaeolus sphinctrinus Fr.
Psathyrella atomata Fr.
Fomes annosus Fr.
Polystictus versicolor (Linn.) Fr.
Daedalea quercina (Linn.) Fr.
Irpex obliquus (Schrad.) Fr.
Radulum orbiculare Fr.
Odontia bicolor (A. & S.) Bres., farinacea (Pers.) Quél.
Mycoleptodon fimbriatum (Pers.) Bourd. and Galz.
Stereum hirsutum (Willd.) Fr.
Hymenochaete corrugata (Fr.) Lév., tabacina (Sow.) Lév.
Corticium laeve (Pers.) Fr., niveo-cremeum v. Hoehn. & Litsch., Sambuci (Pers.) Fr., Pearsonii Bourd., comedens (Nees) Fr., porosum Berk. & Curt., praetermissum (Karst.) Bres.
Peniophora glebulosa (Fr.) Bres., pallidula Bres., longispora (Pat.) v. Hoehn. & Litsch., cremea Bres., gigantea (Fr.) Mass., incarnata (Pers.) Cooke, cinerea (Fr.) Cooke, laevigata (Fr.) Mass.
Auricularia Auricula-Judae (Linn.) Schroet.
Exidia glandulosa (Bull.) Fr., nucleata (Schwein.) Rea.

UREDINEAE.

Uromyces Ficariae (Schum.) Lév., Valerianae (Schum.) Fuck., Scillarum (Grev.) Wint., Dactylidis Otth., Poae Rabenh.
Puccinia fusca (Relh.) Wint., Anemones Pers., Violae (Schum.) DC., Lychnidearum Link, Umbilici Guep., Aegopodii (Schum.) Mart., tumida Grev., albescens Grev., Adoxae Hedw. fil, Lampsanae (Schultz.) Fuck., Taraxaci Plowr., obscura Schroet., Caricis (Schum.) Rebent., holcina Erikss., dispersa (sens. lat.) Erikss. & Henn. on *Aira caespitosa*, graminis Pers. on *Agropyrum repens*, oblongata (Link) Wint. on *Luzula maxima*.
Phragmidium violaceum (Schultz.) Wint., Fragariae (DC.) Wint.
Melampsora Rostrupii Wagn. (=Caeoma Mercurialis (Mart.) Link).
Melampsoridium betulinum (Pers.) Kleb.
Milesina Scolopendrii (Fuck.) Jaap, Kriegeriana P. Magn., Polystichi (Wineland) Grove.

PYRENOMYCETES.

Sphaerotheca tomentosa Otth. on *Euphorbia amygdaloides*.
Erysiphe Polygoni DC. on *Heracleum*, graminis DC.
Nectria cinnabarina (Tode) Fr., mammoidea Phil. & Plowr., sanguinea (Sibth.) Fr., episphaeria (Tode) Fr.
Rosellinia aquila (Fr.) de Not.

* The localities for Monmouthshire are not recorded separately, as all were within a few miles of Tintern. A separate list is appended of species collected on the opposite side of the Wye, in Gloucestershire.

Stigmatea Robertiani Fr.
Mycosphaerella hedericola (Desm.) Lindau, maculiformis (Pers.) Schroet.
Venturia Rumicis (Desm.) Wint.
Leptosphaeria acuta (Moug. & Nestl.) Karst.
Leptospora caudata Fuck.
Hypospila Pustula (Pers.) Karst.
Didymella Salicis Grove.
Diaporthe leiphaemia (Fr.) Sacc.
Gnomonia cerastis (Riess) Ces. & de Not.
Eutypa lata (Pers.) Tul., flavo-virescens (Hoffm.) Sacc.
Valsa decorticans Fr.
Diatrypella quercina (Pers.) Nke.
Diatrype Stigma (Hoffm.) de Not., disciformis (Hoffm.) Fr.
Hypoxylon multiforme Fr., coccineum Bull., fuscum Fr.
Xylaria Hypoxylon (L.) Grev.
Daldinia concentrica (Bolt.) Ces. & de Not.
Ustulina vulgaris Tul. (Conidial stage).
Phyllachora graminis (Pers.) Fuck.

HYSTERIACEAE.

Rhopographus Pteridis (Sow.) Wint.
Dichaena faginea Fr., quercina Fr.
Gloniopsis curvata Sacc.

DISCOMYCETES.

Sarcoscypha coccinea (Jacq.) Fr.
Ciliaria scutellata (Linn.) Quél.
Ombrophila clavus (A. & S.) Cooke.
Coryne sarcoides (Jacq.) Tul.
Bulgaria inquinans (Pers.) Fr.
Calloria fusarioides (Berk.) Fr.
Orbilia xanthostigma Fr.
Chlorosplenium aeruginosum (Oeder) de Not. (Mycelium only).
Helotium fructigenum (Bull.) Fuck.
Dasycypha virginea (Batsch) Fr., caulicola Fr.? (on *Pteris* stems).
Trichoscypha calycina (Schum.) Boud.
Arachnopeziza aurelia (Pers.) Fuck.
Micropodia pteridina (Karst.) Boud.
Mollisia cinerea (Batsch) Karst.
Heterosphaeria Patella (Tode) Grev.
Dermatea Cerasi (Pers.) de Not.
Pseudopeziza Trifolii (Biv.-Bern) Fuck., Ranunculi (Wallr.) Fuck., repanda (Fr.) Karst.
Stegia Ilicis Fr.
Colpoma quercinum (Pers.) Wallr.
Rhytisma acerinum (Pers.) Fr.

PHYCOMYCETES.

Synchytrium Taraxaci de By. & Woron., Mercurialis (Lib.) Fuck.

PROTOMYCETACEAE.

Taphridium umbelliferarum (Rostr.) Juel.

SPHAEROPSIDACEAE.

Phyllosticta hedericola Dur. & Mont.
Phoma herbarum West. (on dead stems of *Verbascum*).
Septoria Hederae Desm.

MELANCONIACEAE.

Marssonina Potentillae (Desm.) P. Magn.

HYPHOMYCETES.

Ovularia obliqua (Cooke) Oud.
Botrytis cinerea (Pers.) Fr.
Scolecotrichum graminis Fuck.
Volutella ciliata (A. & S.) Fr.
Vermicularia trichella Fr.

Species found on Gloucestershire side of River Wye.

Panus stipticus (Bull.) Fr.
Polystictus versicolor (Linn.) Fr.
Merulius corium (Pers.) Fr.
Trametes mollis (Sommerf.) Fr.
Corticium caeruleum (Schrad.) Fr., comedens (Nees) Fr.
Peniophora caesia (Bres.) Bourd. & Galz., cinerea (Fr.) Cooke.
Hymenochaete rubiginosa (Dicks.) Lév., corrugata (Fr.) Lév.
Uromyces Scillarum (Grev.) Wint.
Puccinia Violae (Schum.) DC., Hieracii Mart., obscura Schroet., holcina Erikss.
Phragmidium violaceum (Schultz.) Wint., Fragariae (DC.) Wint.
Melampsora Rostrupii Wagn. (Aecidium on *Mercurialis*).
Milesina Polystichi (Wineland) Grove.
Stigmatea Robertiani Fr.
Mycosphaerella maculiformis (Pers.) Schroet.
Hypospila Pustula (Pers.) Karst.
Didymella Salicis Grove.
Cryptosphaeria eunomia (Fr.) Fuck.
Diatrype disciformis (Hoffm.) Fr.
Eutypa lata (Pers.) Tul.
Hypoxylon fuscum Fr., rubiginosum (Pers.) Fr.
Xylaria Hypoxylon (Linn.) Grev.
Phyllachora graminis (Pers.) Fuck.
Rhopographus Pteridis (Sow.) Wint.
Gloniopsis curvata Sacc.
Mitrophora hybrida (Sow.) Boud.
Disciotis venosa (Pers.) Boud.
Sarcoscypha coccinea (Jacq.) Fr.
Ciliaria scutellata (Linn.) Quél., trechispora (B. & Br.) Boud.
Mollisia cinerea (Batsch) Karst.
Pseudopeziza repanda (Fr.) Karst.
Propolis faginea (Schrad.) Karst.
Stegia Ilicis Fr.
Phyllosticta hedericola Dur. & Mont.
Septoria Hederae Desm.

LICHENS OF THE TINTERN FORAY.

By H. H. Knight, M.A.

The rocks in the Tintern district were similar to those met with at the Spring Foray at Matlock last year. In both districts Carboniferous Limestone rocks occur, but instead of the Millstone Grit of Derbyshire we had Old Red Sandstone rocks. The Wye Valley at Tintern however is well wooded, and consequently calcareous lichens were less plentiful than in the exposed valleys of Dovedale and Millers Dale. The most interesting find was *Opegrapha paraxanthodes*, a lichen of shady calcareous rocks.

Several of the lichens in this list were found on sandstone walls; these compared favourably with the grit walls in the Matlock district.

Tree lichens were more numerous than in Derbyshire, though only some of the common species were met with.

The parasitic fungus *Ticothecium rimosicolum* Arn. was found growing on *Rhizocarpon petraeum.*

In the *Journal of Botany*, May 1925, Dr Watson has described under the name *Clathroporina calcarea* a lichen found at the foray last year in Dovedale and Millers Dale.

A few lichens in this list (indicated by the letter *G.*) were found on the left bank of the River Wye in Gloucestershire.

Placynthium nigrum S. F. Gray
Collema cheileum Ach.
C. granuliferum Nyl.
Leptogium lacerum S. F. Gray
Peltigera canina Willd.
P. horizontalis Hoffm.
Parmelia physodes Ach.
P. caperata Ach.
P. sulcata Tayl.
P. dubia Tayl.
P. fuliginosa Nyl. and var. laetevirens Nyl.
Evernia prunastri Ach.
Ramalina farinacea Ach.
Usnea florida Web. var. hirta Ach.
Xanthoria parietina Th. Fr.
X. polycarpa Oliv.
Placodium murorum DC.
P. aurantiacum Anzi var. flavovirescens Anzi
Physcia hispida Tuckerm.
Lecanora subfusca Ach.
L. campestris B. de Lesd.
L. atra Ach.
L. Hageni Ach.
L. varia Ach.
L. polytropa Schaer.
L. parella Ach.
Acarospora fuscata Th. Fr.
Lecania syringea Th. Fr., *G.*
Pertusaria faginea Leight.
P. pertusa Dal. Tor. and Sarnth.
P. leioplaca Schaer.
Phlyctis argena Koerb.
Diploschistes scruposus Norm.
Cladonia sylvatica Hoffm.
C. pyxidata Hoffm.
C. fimbriata Fr.
C. furcata Schrad.
Coenogonium ebeneum A. L. Sm.
Gyalecta cupularis Schaer.
Lecidea lucida Ach.
L. uliginosa Ach.
L. parasema Ach.
L. contigua Fr.
L. sorediza Nyl.
L. confluens Ach.
L. lithophila Ach.
L. fuscoatra Ach., *G.*
Biatorina cyrtella Th. Fr., *G.*
Bilimbia aromatica Jatta
B. sabuletorum Br. & Rostr.
Buellia canescens de Not.
B. myriocarpa Mudd
Rhizocarpon petraeum Massal.
Arthonia lurida Ach. var. spadicea Nyl.
A. radiata Ach.
Opegrapha paraxanthodes Nyl.
Graphis elegans Ach., and f. stellata Leight.
Graphis scripta Ach., and var. pulverulenta Ach.
Verrucaria nigrescens Pers.
Arthopyrenia fallax Arn.
Porina carpinea A. Zahlbr.
P. chlorotica Wainio

THE DUBLIN FORAY.

September 21st to 26th, 1925.

By E. M. Wakefield, M.A., F.L.S.

The twenty-ninth Autumn Foray and Annual General Meeting of the Society was held at Dublin from September 21st to September 26th, at the invitation of a committee of well-known Irish botanists.

Most of the party were very comfortably housed at the Standard Hotel, but meetings were held at the Royal College of Surgeons, where Professor J. Alfred Scott had placed at our disposal not only a room for meetings and the reading of papers, but also a laboratory for work and the exhibition of specimens. In addition, through the kind offices of Miss Knowles and Mr Gorman, books from the libraries of the Natural History Museum and of the College of Science were available for use, so that facilities for the naming of material on the spot were better than usual. This, and the inclusion in the party of several members interested chiefly in parasitic fungi, perhaps in part accounts for the large number of Fungi Imperfecti recorded, species of *Ramularia* in particular being unusually numerous.

The majority of the party, including about twenty members who had crossed the Irish Channel, assembled on Monday evening, September 21st, but various members had taken advantage of an excursion ticket which brought them a few days earlier, and had already carried out some preliminary skirmishes. Mr Muskett and Mr Carrothers brought from the neighbourhood of Belfast a number of the larger fungi, which made an interesting first exhibit.

The first "official" expedition was a whole day on Tuesday in the beautiful Powerscourt Demesne, a start being made from the Hotel at 9.30 a.m. Heavy rain was experienced in the middle of the day, but there was compensation in seeing the fine waterfall at its best. In the afternoon the sun came out and wet feet and dripping waterproofs were soon forgotten, particularly over a substantial Irish tea provided at the Lodge at the end of the day.

The Powerscourt estate yielded some of the best finds of the week amongst the larger fungi, for instance *Lepiota lenticularis*, *Pleurotus geogenius*, *Leptonia chalybea*, *Psaliota haemorrhoidaria* (found in abundance in an open grassy spot), and various species of *Hygrophorus* and *Inocybe*.

Cortinarii were rare, as all through the week, only a few of the smaller and more common species being found. The impression gained was that the "run" of Agarics had not yet

properly developed, and from reports received since as to their unkind behaviour in coming up in abundance after we had left, this appears to have been the case.

On Tuesday evening at 8.45, the Annual General Meeting was held. In the unfortunate absence of the President owing to illness, the chair was taken by the Vice-President, Mr J. Ramsbottom. Dr G. H. Pethybridge was unanimously elected as President for 1926, with Dr E. J. Butler as Vice-President. In place of Mr Dowson and Mr Sharpe, the retiring members of Council, Mr W. Buddin and Mr F. G. Gould were elected. The other officers remain as before except that Mr Pearson resigned the office of Foray Secretary*. Miss Wakefield was asked to represent the Society at the British Association meeting at Oxford in 1926. For the 1926 Autumn Foray several invitations had been received. After some discussion it was decided to arrange a joint foray with the Woolhope Club at Hereford in 1926, and if possible a foray with the Scottish Cryptogamic Society in 1927. Finally the meeting heard with much pleasure and gratitude that the President, Mr W. N. Cheesman, had presented to the Society the sum of one hundred guineas, to be invested, and the interest to be used as the Council should think best.

On the Wednesday visits to the Universities, Museum, and Glasnevin Botanic Gardens filled up the morning, and these were followed by lunch by kind invitation with the Dublin Rotary Club, when Mr Ramsbottom gave a short address on "Mycology and Human Affairs." After lunch an expedition was made to Howth, where various additions to the list of microfungi were made. Members who had been to Glasnevin brought back the interesting *Rhizosphaera Kalkhoffii* Bub., only recently recorded in Scotland on the same host, *Picea pungens*.

In the evening, in the absence of the usual Presidential address, Mr Ramsbottom gave a talk on "The Ecology of Fungi."

On Thursday a start was made at 11.30 a.m. for Carton Demesne. Here the ground first covered was a mixed plantation of Conifers and Dicotyledonous trees, traversed by wide grassy rides, which provided good hunting for both large and small fungi. *Hebeloma fastibile* was fairly common in the rides, and evidence of the presence of Conifers was provided by such species as *Boletus viscidus*, *B. elegans*, and *Tremellodon gelatinosum*. After leaving this plantation the party worked through

* At a meeting of the Council held November 6th, it was decided not to appoint a separate Foray Secretary, but that the Secretary should carry out the general arrangements, and that where possible a temporary local secretary should be nominated to undertake the necessary local details.

Bog Wood towards the lake, finally meeting for tea at the curious "Shell Cottage." One of the kind thoughts of our guides which was much appreciated was the provision of small photographic reproductions of the Ordnance maps of the ground worked each day, whereby even the most incorrigible strays were enabled to turn up for tea and the return home at the hour specified. *Fomes annosus* was found on ash, on which host it has also been seen at Kew. In addition to the larger fungi, numerous micro-fungi were recorded on this day, including various species of *Ramularia*, *Cercospora Opuli* on *Viburnum Opulus*, *Microsphaeria Euonymi* showing perithecia, *Puccinia Buxi*, and *Milesina Scolopendrii*.

In the evening the members were entertained at dinner at University College by the Dublin Natural History Society.

On Friday Kilruddery, the property of Lord Ardee, was visited. The members were received by Lady Ardee and first shown over the house, and afterwards her agent Mr Le Fanu acted as guide through the grounds. Unfortunately rain was again experienced, but in spite of it a very fair bag was made, notably of the smaller forms.

In the evening a number of our Irish friends joined us at dinner at the hotel, and afterwards attended the final meeting, when comments on the finds of the week were made by Miss Lister, Miss Lorrain Smith, Miss Wakefield, Mr Pearson and Mr Ramsbottom. In conclusion the usual votes of thanks to landowners, etc., were passed, and particularly hearty thanks were expressed for the great kindness we had experienced in every way in Dublin.

The following list includes not only the species gathered during the official period of the Foray, but also numerous finds made by early arrivals. Thus Dr Butler had collected various fungi at Malahide, and Miss Lister brought in *Polyporus hispidus*, *P. squamosus*, and *Ganoderma applanatum* from near Dublin. The records from the Scalp and Enniskerry were made by some of the members who had arrived on Saturday and were taken a most enjoyable expedition on the Sunday. Mr Cotton stayed after the end of the Foray and brought back a few additional records from Avondale.

The ground covered includes more than one county. Thus while the Scalp, Malahide and Howth are in Co. Dublin, Powerscourt, Enniskerry, and Kilruddery are in Co. Wicklow, and Carton is in Co. Kildare.

For assistance in compiling the list the Secretary is indebted to all the members present, and more particularly to Mr Ramsbottom, Dr Butler, Mr Pearson, and Mr Buddin.

The species marked with an asterisk are not included in

either Adams and Pethybridge, *Census Catalogue of Irish Fungi* (1910) or Rea and Hawley's list of fungi in the Clare Island Survey reports (1912). The further mark † indicates that these species are apparently new to the British Flora.

Complete List of Species gathered during the Foray.

S. = the Scalp; *E.* = Enniskerry; *P.* = Powerscourt; *H.* = Howth; *C.* = Carton Demesne; *K.* = Kilruddery.

HYMENOMYCETES.

Amanita phalloides (Vaill.) Fr., *S.*, *P.*, *K.*, mappa (Batsch) Fr., *S.*, *P.*, pantherina (DC.) Fr., *P.*

Amanitopsis vaginata (Bull.) Roze, *H.*, strangulata (Fr.) Roze, *C.*

Armillaria mellea (Vahl) Fr., *P.*, *K.*, (rhizomorphs only) *E.*, *H.*, *C.*, *K.*

Lepiota procera (Scop.) Fr., *P.*, rhacodes (Vitt.) Fr., *P.*, acutesquamosa (Weinm.) Fr., *C.*, amaianthina (Scop.) Fr., *K.*, carcharias (Pers.) Fr., *P.*, lenticularis (Lasch) Cooke*, *P.*

Tricholoma rutilans (Schaeff.) Fr., *H.*, *C.*, *K.*, terreum (Schaeff.) Fr., *P.*, argyraceum (Bull.) Fr.*, *P.*, cuneifolium Fr., *P.*, saponaceum Fr., *P.*, sulphureum (Bull.) Fr., *K.*, album (Schaeff.) Fr., *P.*, nudum (Bull.) Fr., *P.*, cinerascens (Bull. non Fr.) Quél., *P.*, *K.*, melaleucum (Pers.) Fr., *P.*, *C.*, *K.*

Clitocybe aurantiaca (Wulf.) Studer, *S.*, *P.*, *H.*, *K.*, cerussata Fr., *C.*, flaccida (Sow.) Fr., *P.*, fragrans (Sow.) Fr., *P.*, *C.*

Laccaria laccata (Scop.) B. & Br., *P.*, *H.*, *C.*

Collybia radicata (Relh.) Berk., *H.*, *K.*, maculata (A. & S.) Fr., *P.*, cirrhata (Schum.) Fr., *K.*, ambusta Fr.*, *P.*, atrata Fr., *P.*

Mycena lineata (Bull.) Fr.*, *K.*, rugosa Fr., *C.*, *K.*, galericulata (Scop.) Fr., *P.*, *K.*, polygramma (Bull.) Fr., *H.*, *K.*, inclinata Fr.*, *P.*, *C.*, *K.*, alcalina Fr., *P.*, ammoniaca Fr., *P.*, *C.*, metata Fr., *K.*, vitilis Fr., *P.*, *K.*, haematopus (Pers.) Fr., *P.*, sanguinolenta (A. & S.) Fr., *S.*, *P.*, *H.*, *K.*, galopus (Pers.) Fr., *P.*, *H.*, *C.*, *K.*, var. alba Fl. Dan.*, *C.*, var. nigra Fl. Dan., *P.*, pelliculosa Fr., *P.*, rorida Fr., *C.*, stylobates (Pers.) Fr., *C.*, corticola (Schum.) Fr., *P.*

Omphalia pyxidata (Bull.) Fr., *H.*, *S.*, umbellifera (Linn.) Fr., *S.*, fibula (Bull.) Fr., *P.*, *C.*, *K.*

Pleurotus ostreatus (Jacq.) Fr., *H.*, geogenius (DC.) Fr.*, *P.*, applicatus (Batsch) Berk., *P.*

Hygrophorus limacinus Fr.*, *C.*, *K.*, pratensis (Pers.) Fr., *P.*, *K.*, virgineus (Wulf.) Fr., *P.*, niveus (Scop.) Fr., *P.*, subradiatus (Schum.) Fr., var. lacmus Fr.*, *P.*, coccineus (Schaeff.) Fr., *P.*, miniatus Fr., *P.*, puniceus Fr., *P.*, obrusseus Fr., *P.*, *K.*, conicus (Scop.) Fr., *P.* (yellow form), *C.*, *K.*, chlorophanus Fr., *P.*, psittacinus (Schaeff.) Fr., *P.*

Lactarius turpis (Weinm.) Fr., *E.*, *H.*, pubescens Fr., *C.*, blennius Fr., *K.*, circellatus Fr., *H.*, vellereus Fr., *C.*, deliciosus (Linn.) Fr., *P.*, pallidus (Pers.) Fr., *P.*, quietus Fr., *S.*, *P.*, *K.*, vietus Fr., *H.*, glyciosmus Fr., *H.*, serifluus (DC.) Fr., *E.*, mitissimus Fr., *P.*, subdulcis (Pers.) Fr., *P.*

Russula chloroides (Krombh.) Bres.*, *P.*, *K.*, nigricans (Bull.) Fr., *E.*, *K.*, adusta (Pers.) Fr., *P.*, lepida Fr., *K.*, cyanoxantha (Schaeff.) Fr., *S.*, *P.*, furcata (Pers.) Fr., *S.*, ochroleuca (Pers.) Fr., *S.*, *H.*, *C.*, *K.*, fellea Fr., *P.*, *H.*, sanguinea (Bull.) Fr.*, *P.*, drimeia Cooke, *S.*, *P.*, fragilis (Pers.) Fr., *P.*, *H.*, *K.*, var. fallax (Schaeff.) Mass., *S.*, *P.*, *C.*, *K.*, caerulea Cooke, *S.*, lutea (Huds.) Fr., *P.*, var. armeniaca (Cooke) Rea, *P.*, atropurpurea (Krombh.) Maire, *K.*

Cantharellus cibarius Fr., *P.*

Marasmius peronatus (Bolt.) Fr., *P.*, *H.*, *K.*, oreades (Bolt.) Fr., *E.*, erythropus (Pers.) Fr., *K.*, hariolorum (DC.) Quél., *P.*, *C.*, *K.*, dryophilus (Bull.) Karst., *P.*, *H.*, *K.*, ramealis (Bull.) Fr., *H.*

Androsaceus rotula (Scop.) Pat., *P.*, *H.*, *C.*, *K.*, androsaceus (Linn.) Pat., *P.*, *H.*

Panus torulosus (Pers.) Fr., *P.*, *K.*, stipticus (Bull.) Fr., *P.*
Volvaria parvula (Weinm.) Fr., *P.*
Pluteus cervinus (Schaeff.) Fr., *P.*, *C.*, *K.*, nanus (Pers.) Fr., var. lutescens Fr.*, *C.*, *K.*
Entoloma sericeum (Bull.) Fr., *P.*, *C.*, *K.*
Leptonia chalybaea (Pers.) Fr., *P.*
Nolanea pascua (Pers.) Fr., *S.*, papillata Bres.*, *P.*
Clitopilus prunulus (Scop.) Fr., *K.*
Paxillus involutus (Batsch) Fr., *P.*, *H.*, *K.*, panuoides Fr., *P.*
Pholiota erebia Fr., *P.*, *C.*, squarrosa (Müll.) Fr., *H.*, *K.*, adiposa Fr., *K.*, mutabilis (Schaeff.) Fr., *P.*, *K.*, marginata (Batsch) Fr., *K.*
Inocybe pyriodora (Pers.) Fr., *P.*, rimosa (Bull.) Fr., *P.*, *C.*, tomentosa (Jungh.) Quél., *P.*, geophylla (Sow.) Fr., *C.*, *K.*, var. lilacina Fr., *P.*, *C.*, *K.*, Godeyi Gill., *P.*, *H.*, obscura (Pers.) Fr., *C.*, flocculosa Berk.*, *P.*, cincinnata Fr., *P.*, calamistrata Fr., *S.*, fastigiata (Schaeff.) Fr., *K.*
Astrosporina proximella (Karst.) Rea*, *P.*, praetervisa (Quél.) Schroet.*, *C.*, calospora (Quél.) Rea*, *P.*
Hebeloma fastibile Fr., *C.*, crustuliniforme (Bull.) Fr., *P.*, *H.*, *C.*, var. minus Cooke*, *C.*
Flammula ochrochlora Fr.*, *P.*, carbonaria Fr.*, *P.*, *K.*
Naucoria Cucumis (Pers.) Fr.*, *P.*, melinoides Fr., *P.*, escharoides Fr., *C.*, *K.*
Galera tenera (Schaeff.) Fr., *H.*, *C.*, hypnorum (Schrank) Fr., *H.*
Tubaria furfuracea (Pers.) W. G. Sm., *P.*, *C.*, *K.*, pellucida (Bull.) Fr., *P.*
Crepidotus mollis (Schaeff.) Fr., *P.*, *K.*
Cortinarius (Myxacium) elatior Fr., *P.*
Cortinarius (Telamonia) hinnuleus (Sow.) Fr., *P.*, *C.*, *K.*, brunneus (Pers.) Fr., *P.*, flexipes Fr.*, *C.*, rigidus (Scop.) Fr., *P.*, paleaceus (Weinm.) Fr., *C.*, *K.*
Psaliota campestris (Linn.) Fr., *P.*, *C.*, *K.*, haemorrhoidaria Kalchbr., *P.*
Stropharia semiglobata (Batsch) Fr., *P.*, *H.*, *K.*, aeruginosa (Curt.) Fr., *K.*
Hypholoma fasciculare (Huds.) Fr., *S.*, *H.*, *C.*, *K.*, sublateritium (Schaeff.) Fr., *C.*, pyrotrichum (Holmsk.) Fr.*, *P.*, pilulaeforme (Bull.) Fr.*, *K.*, hydrophilum (Bull.) Fr., *P.*, *K.*
Psilocybe sarcocephala Fr.*, *P.*, uda (Pers.) Fr., *P.*, semilanceata Fr., *H.*, *C.*, *K.*, spadicea Fr., *K.*
Psathyra corrugis (Pers.) Fr., *P.*, *K.*, fibrillosa (Pers.) Fr., *P.*, *C.*, *K.*
Psathyrella gracilis Fr., *P.*, *H.*, *C.*, *K.*, atomata Fr., *C.*
Panaeolus sphinctrinus Fr., *H.*, *K.*, campanulatus (Linn.) Fr., *P.*, *C.*, *K.*
Anellaria separata (Linn.) Karst., *C.*
Bolbitius titubans (Bull.) Fr., *C.*, *K.*
Coprinus comatus (Fl. Dan.) Fr., *P.*, *H.*, *C.*, *K.*, sterquilinus Fr.*, *P.*, *C.*, atramentarius (Bull.) Fr., *K.*, niveus (Pers.) Fr., *H.*, micaceus (Bull.) Fr., *H.*, *K.*, Hendersonii Berk.*, *C.*, *K.*, domesticus (Pers.) Fr., *K.*, lagopus Fr., *C.*, *K.*, plicatilis (Curt.) Fr., *P.*, *H.*, *C.*, *K.*
Gomphidius viscidus (Linn.) Fr., *P.*, *C.*, *K.*
Lenzites betulina (Linn.) Fr.*, *P.*
Boletus elegans (Schum.) Fr., *P.*, *C.*, viscidus (Linn.) Fr., *C.*, granulatus (Linn.) Fr., *P.*, badius Fr., *P.*, chrysenteron (Bull.) Fr., *S.*, *P.*, *K.*, subtomentosus (Linn.) Fr., *S.*, edulis (Bull.) Fr., *E.*, scaber (Bull.) Fr., *E.*
Fistulina hepatica (Huds.) Fr., *C.*
Polyporus varius Fr., *P.*, squamosus (Huds.) Fr., *P.*, *H.*, *C.*, sulphureus (Bull.) Fr., *P.*, *K.*, giganteus (Pers.) Fr., *C.*, *K.*, betulinus (Bull.) Fr., *P.*, *H.*, dryadeus (Pers.) Fr., *P.*, hispidus (Bull.) Fr., *K.*, adiposus B. & Br.*, *H.*, adustus (Willd.) Fr., *P.*, caesius (Schrad.) Fr., *P.*
Fomes annosus Fr., *P.*, *C.*, *K.* (on Ash), connatus Fr., *K.* (on Elm).
Ganoderma applanatum (Pers.) Pat., *H.*, *C.*, *K.*
Polystictus versicolor (Linn.) Fr., *E.*, *H.*, *K.*, abietinus (Dicks.) Fr., *K.*
Ptychogaster albus Corda, *K.*
Daedalea biennis (Bull.) Quél., *P.*, quercina (Linn.) Fr., *P.*
Merulius corium (Pers.) Fr., *C.*, *K.*, lacrymans (Wulf.) Fr., *Dublin*, fugax Fr.*, *S.*
Hydnum repandum (Linn.) Fr., *E.*

Caldesiella crinalis (Fr.) Bourd. & Galz., *P.*
Radulum orbiculare Fr., *H.*
Acia uda (Fr.) Bourd. & Galz., *C.*
Grandinia granulosa Fr., *Malahide.*
Irpex obliquus (Schrad.) Fr., *P.*, *H.*, *C.*, *K.*
Phlebia merismoides Fr., *C.*
Hypochnus ferrugineus (Pers.) Fr., *K.*, fuscus (Pers.) Fr.*, *P.*
Stereum spadiceum Fr., *P.*, rugosum (Pers.) Fr., *P.*, *H.*, hirsutum (Willd.) Fr., *P.*, *C.*, *K.*, purpureum (Pers.) Fr., *P.*, *C.*
Hymenochaete rubiginosa (Dicks.) Lév., *P.*
Corticium laeve (Pers.) Fr., *P.*, *H.*, *C.*, *K.*, arachnoideum Berk., *S.*, Sambuci (Pers.) Fr., *Malahide*, *C.*, *K.*, confluens Fr., *Malahide*, *P.*, comedens (Nees) Fr., *P.*, porosum Berk. & Curt., *K.*, praetermissum (Karst.) Bres.*, *P.*
Peniophora Aegerita v. Hoehn. & Litsch.*, *K.*, pallidula Bres.*, *E.*, longispora (Pat.) v. Hoehn. & Litsch.*, *E.*, setigera (Fr.) Bres.*, *C.*, cinerea (Fr.) Cooke, *E.*, *H.*, *C.*, *K.*, quercina (Pers.) Cooke, *P.*, *C.*, *K.*
Coniophora puteana (Schum.) Fr., *Dublin.*
Clavaria inaequalis (Müll.) Fr., *P.*, *K.*, vermicularis Fr., *P.*, fumosa (Pers.) Fr., *P.*
Pistillaria quisquiliaris Fr., *S.*, *P.*, puberula Berk., *P.*
Auricularia auricula-Judae (Linn.) Schroet., *P.*, *H.*, *C.*, *K.*
Tremella mesenterica (Retz.) Fr., *P.*, *K.*
Exidia glandulosa (Bull.) Fr., *H.*, *C.*, nucleata (Schw.) Rea*, *C.*, Thuretiana (Lév.) Fr.*, *P.*, *C.*
Tremellodon gelatinosum (Scop.) Pers.*, *P.*, *C.*
Dacryomyces deliquescens (Bull.) Duby, *S.*, *P.*, *K.*
Calocera viscosa (Pers.) Fr., *E.*, *K.*, cornea (Batsch) Fr., *P.*, stricta Fr., *P.*, *C.*

GASTROMYCETES.

Mutinus caninus (Huds.) Fr., *P.*
Phallus impudicus (Linn.) Pers., *P.*, *K.*
Crucibulum vulgare Tul., *K.*
Lycoperdon caelatum (Bull.) Fr., *H.*, perlatum Pers., *P.*, *C.*, *K.*, pyriforme (Schaeff.) Pers., *E.*, *P.*, *C.*, *K.*
Scleroderma aurantium Pers., *P.*, *C.*, *K.*, Geaster Fr., *P.*, *C.*, *K.*

UREDINEAE.

Uromyces Fabae (Pers.) de Bary, on *Vicia sepium*, *P.*, Valerianae (Schum.) Fuck., *C.*, Scrophulariae (DC.) B. & Br.*, *E.*, Poae Rabenh.* (Aecidium on *Ranunculus*), *P.*
Puccinia Violae (Schum.) DC., *H.*, *C.*, *K.*, Lychnidearum Link*, *P.*, Malvacearum Mont., *Dublin*, Circaeae Pers., *E.*, *P.*, Saniculae Grev., *E.*, *P.*, *K.*, obtegens (Link) Tul., *E.*, Glechomatis DC., *P.*, Buxi DC., *C.*, *K.*, obscura Schroet, *S.*, Caricis (Schum.) Rebent., *K.*, holcina Erikss.*, *H.*, Poarum Niels. (Aecidium on *Tussilago*), *E.*, *H.*, *C.*
Triphragmium Ulmariae (Schum.) Link, *C.*
Phragmidium Fragariastri (DC.) Schroet. on *Potentilla reptans*, *K.*, subcorticium (Schrank) Wint., *P.*, *H.*, *C.*, violaceum (Schultz) Wint., *E.*, *P.*, *H.*, Rubi-Idaei (Pers.) Karst., *C.*
Coleosporium Petasitis de Bary, *P.*, *C.*, Tussilaginis (Pers.) Kleb., *E.*, *P.*, *H.*, *C.*, *K.*
Pucciniastrum Circaeae (Schum.) Schroet.*, *P.*, *C.*, *K.*
Milesina Dieteliana Magn.*, *P.*, Scolopendrii (Fuck.) Jaap*, *P.*, *H.*, *C.*
Melampsora Hypericorum (DC.) Schroet., *K.*
Melampsoridium betulinum (Pers.) Kleb., *C.*, *K.*
Melampsorella Caryophyllacearum (DC.) Schroet.* (= Aecidium elatinum A. & S.) on *Abies pectinata*, *K.*, *A. cephalonica* & *A. Lowiana*, *Avondale.*

USTILAGINEAE.

Ustilago Scabiosae (Sow.) Wint., *K.*

PYRENOMYCETES.

Sphaerotheca pannosa (Wallr.) Lév., *K.*
Uncinula Aceris (DC.) Sacc., *P., H., C.,* & *Longtown,* Co. Kildare.
Microsphaeria Euonymi (DC.) Sacc., *C.* (perithecia), quercina (Schw.) Burr., *C., K.*
Erysiphe Cichoracearum DC. on *Taraxacum, H.,* Polygoni DC. on *Heracleum, E., H., K., Angelica, E., Circaea, P., Trifolium* spp., *H.,* and *Lotus corniculatus, K.,* graminis DC., *E., C.*
Nectria coccinea (Pers.) Fr., *K.,* cinnabarina (Tode) Fr., *H., C., K.*
Hypocrea rufa (Pers.) Fr., *P.*
Claviceps purpurea (Fr.) Tul., *C.*
Chaetomium elatum Kunze, *C.*
Stigmatea Robertiani Fr., *C., K.*
Mycosphaerella Fragariae (Tul.) Lindau*, *P.,* Iridis (Awd.) Schroet.*, *K.*
Venturia Rumicis (Desm.) Wint., *P.*
Ophiobolus porphyrogonus (Tode) Sacc.*, *C.*
Diaporthe taleola (Fr.) Sacc.*, *C.,* Aucubae Sacc.*, *Avondale.*
Eutypa lata Tul., *C.*
Diatrype disciformis (Hoffm.) Fr., *H.*
Diatrypella quercina (Pers.) Nke., *C.*
Hypoxylon multiforme Fr., *C.*
Xylaria Hypoxylon (Linn.) Grev., *P., H., C., K.*
Ustulina vulgaris Tul., *E.*
Phyllachora graminis (Pers.) Fuck., *C., K.*
Endodothella Junci (Fr.) Theiss. & Syd.*, *P.*

HYSTERIACEAE.

Rhopographus Pteridis (Sow.) Wint., *S., P., H.*

DISCOMYCETES.

Helvella crispa (Scop.) Fr., *P., C.*
Aleuria vesiculosa (Bull.) Boud., *H.*
Otidea onotica (Pers.) Fuck., *C.,* leporina (Batsch) Fuck., *C.*
Peziza aurantia Pers., *P.*
Ciliaria scutellata (Linn.) Quél., *H., C.*
Coprobia granulata (Bull.) Boud., *C.*
Calycella citrina (Hedw.) Quél., *C.*
Coryne sarcoides (Jacq.) Tul., *P., C., K.*
Orbilia xanthostigma Fr., *H., C.*
Sclerotinia Curreyana (Berk.) Karst.*, *P., H.*
Phialea firma (Pers.) Gill., *P.*
Chlorosplenium aeruginosum (Oeder) de Not. (mycelium only), *C.*
Helotium herbarum (Pers.) Fr., *C.,* fructigenum (Bull.) Fuck., *H., C.*
Dasyscypha virginea (Batsch) Fuck., *P., C.*
Trichoscypha calycina (Schum.) Boud., *P.*
Mollisia cinerea (Batsch) Karst., *S., P., H.*
Phacidium multivalve (DC.) Kunze & Schm., *P.*
Pseudopeziza Trifolii (Biv.-Bern) Fuck., *H., K.,* Ranunculi (Wallr.) Fuck. on *Anemone, C.*
Stegia Ilicis Fr., *E., P.*
Colpoma quercinum (Pers.) Wallr.*, *C.*
Rhytisma acerinum (Pers.) Fr., *E., P., H., C., K.*

PHYCOMYCETES.

Syzygites megalocarpus Ehrb., *P., K.*
Cystopus cubicus (Strauss) de Bary (C. Tragopogonis Schroet.), *K.*
Phytophthora infestans (Mont.) de Bary, *E., P., K.*
Plasmopara nivea (Ung.) Schroet. on *Heracleum, P., K.*
Bremia Lactucae Regel on Lettuce, *Dublin.*
Peronospora Potentillae de Bary*, *P., K.,* alta Fuck.* on *Plantago media, C.*

PROTOMYCETACEAE.

Taphridium umbelliferarum (Rostr.) Juel*, on *Heracleum, H.*

SPHAEROPSIDEAE.

Phyllosticta hedericola Dur. & Mont.*, *E., H., K.*
Phoma samararum Desm.*, *P.*, leucostigma (DC.) Sacc.* on *Rhododendron, C.*
Rhizosphaera Kalkhoffii Bubák*, on *Picea pungens, Glasnevin.*
Ascochyta Nymphaeae Pass.*†, *Glasnevin.*
Darluca Filum (Biv.) Cast.* on *Puccinia Caricis, K.*
Actinonema Rosae (Lib.) Fr., *Dublin, H., K.*
Septoria Hederae Desm.*, *P., H.*, Rosae Desm.*, *K.*, Rubi West.*, *E., P.*
Coniothyrium Fuckelii Sacc.*, *H.*
Gloeosporium Helicis (Desm.) Oud.*, *H.*
Marssonina Potentillae (Desm.) Magnus*, *K.*
Steganosporium pyriforme (Hoffm.) Sacc.*, *Malahide.*
Vermicularia Dematium (Pers.) Fr., *H.*, trichella Fr.*, *H.*

HYPHOMYCETES.

Trichoderma viride (Pers.) Fr., *K.*
Botrytis cinerea Pers. (sclerotia on *Scilla nutans*), *P.*
Sepedonium chrysospermum (Bull.) Fr., *E.*
Ovularia obliqua (Cooke) Oud.*, *E., P., K., Glasnevin.*
Ramularia Ajugae (Niessl.) Sacc., *P.*, calcea (Desm.) Ces., *E., P., C., K.*, Cirsii Allesch.*, *P.*, Epilobii Allesch.*† on *Epilobium hirsutum, C.*, Heraclei (Oud.) Sacc.*†, *H.*, Hypochoeridis Magn.*, *K.*, filaris Fres. var. Lappae Bres.*, *P.*, lactea (Desm.) Sacc.*, *P., K.*, plantaginea Sacc. & Berl.* on *Plantago lanceolata, K.*, Primulae Thuem.*, *E., P., C., K.*, sambucina Sacc., *P.*, Scrophulariae Fautr. & Roum.*, *E.*, Urticae Ces., *E.*, variabilis Fuck.*, *P.*, nymphaearum (Allesch.) Ramsb., on *Nuphar, Glasnevin.*
Cladosporium herbarum (Pers.) Link, *E.*
Bispora monilioides Corda, *P., K.*
Fusicladium depressum (B. & Br.) Sacc., on *Angelica, E.*
Polythrincium Trifolii Kunze, *K.*
Cercospora Opuli (Fuck.) v. Hoehn., *C.*†
Fumago vagans Pers., *Dublin.*
Tuberculina persicina (Ditm.) Sacc. on *Uromyces Scrophulariae, E.*

LICHENS OF THE DUBLIN FORAY.

By A. L. Smith and M. C. Knowles.

The Dublin Foray was, as far as lichens are concerned, most wisely organised: the thanks of the lichenologists are due to the members of committee who selected districts that in their conditions of atmosphere and temperature were so well suited to lichen growth. The expeditions were planned so that the members were taken right out into the country away from the smoke of the city, and opportunity was given for collecting both rock and tree specimens: each day's excursion was marked by some special feature of open dale or of enclosed woodland with its particular lichen flora and in all the districts lichen growth was abundant and varied.

Before the main party arrived a visit was made by a few of the members to that part of the Dublin Mountains called the

Scalp and to the beautiful Glensink ending up at the village of Enniskery. The boulders that were "confusedly hurled" over the hills at the Scalp were worked over, as far as was possible, in the limited time: they were covered with crustaceous forms in great white or dark masses, with many grey patches of leafy forms such as *Parmelia saxatilis*, the isidiose form of that species, there and elsewhere being unusually abundant. Some tree specimens were secured in Glensink and Rhizocarpons and Verrucarias from stones on the banks of the stream.

Powerscourt Demesne was the field of the first whole-day excursion. The ancient trees in the park and near the waterfall bore great sheets of *Lobaria pulmonaria*, *Cetraria glauca* and several of the larger *Parmeliae*, with other crustaceous, leafy or shrubby lichens on the trees, rocks or walls. *Pertusariae*, notably *P. pertusa* and *P. globulifera*, were abundant.

Carton Demesne was next visited: before leaving the highroad a bridge and a wall of limestone held the attention of the lichenologists a considerable time. White masses of *Aspicilia calcarea* which might have been aptly designated "spill o' the pail" alternated with the dark characteristic lime-loving Collemas and Leptogiums, the black *Placynthium nigrum* and brightly coloured orange species of *Placodium*. Within the Demesne and on the way up the lovely wooded glen many trees were examined and yielded species of *Graphideae* and Pyrenolichens with a few *Lecanorae* and *Lecideae*. And here may be pointed out the rare occurrence of *Lecanora varia* so abundant in the woods near London; *Lecidea parasema* was also rarely seen. At a further stage in the walk overhanging masses of lime cliffs by the side of the path were dotted with *Verrucaria* fructifications and adorned with several species of glowing orange *Placodii*. One small section was covered with crowded whitey-grey growths of *Dermatocarpon miniatum*, almost the colour of the cliffs when gathered, but changing to a darker brownish hue in the collecting boxes. The difficulty in many instances was to secure sufficient material of the minute forms for microscopic examination in the laboratory: hammer and chisel were almost unavailing against the smooth hard rock face.

The final excursion was to Kilruddery, where again we had most cordial and kind permission to go through the grounds. On the low wall of an ancient fountain pool were found *Physcia tribacia* and *Ph. orbicularis* with var. *virella* in closely appressed patches. The chief collecting there, however, was done on trees. Some old and massive trunks were found to be covered with a variety of crustaceous forms; but the outstanding species at Kilruddery was *Pyrenula nitida* which covered trunk after trunk of a long avenue of limes. Other crustaceous lichens such as

Bacidia luteola, Lecanora rugosa, Pertusariae, etc., were gathered, but *Pyrenula* was the most abundant of all. Kilruddery lies in the heart of the mountains and there as on the other excursions we were gladdened by views on every side of that most beautiful tract of country.

The arrangement followed in this list is that of *The Handbook of British Lichens.* The letters which come after the names of the species and varieties signify the localities in which the lichens were collected, viz. *S.* = Scalp, *G.* = Glensink and Killegar, *P.* = Powerscourt, *C.* = Carton and *K.* = Kilruddery. With the exception of Carton, the seat of the Duke of Leinster, which lies inside the Co. Kildare border, all these places are in Co. Wicklow.

Altogether 191 species and varieties have been identified, of these five are now recorded from Ireland for the first time, viz. *Biatorella flava, B. privigna, Biatorina Bouteillei, B. graniformis* and *Verrucaria parva.* Much of the success both of collection and determination of species is due to the untiring interest of Mr Paulson who was fortunately able to be with the party on two of the chief excursions.

EPHEBIACEAE.

Placynthium nigrum S. F. Gray, *S., P., K., C.*
P. nigrum S. F. Gray var. psotina Hue, *K., C.*

COLLEMACEAE.

Collema pulposum Ach., *P., C.*
C. multifidum Schaer., *C.*
C. multipartitus Mudd, *C.*
Leptogium sinuatum Massal., *P.*
L. lacerum S. F. Gray, *C.*
L. lacerum var. pulvinatum Koerb., *C.*

PANNARIACEAE.

Pannaria rubiginosa Del. var. conoplea Koerb., *P.*

PELTIGERACEAE.

Peltigera canina Willd., *S., G., P., K., C.*
P. polydactyla Hoffm., *P.*
P. horizontalis Hoffm., *P.*

STICTACEAE.

Lobaria laciniata Wain., *P.*
L. pulmonaria Hoffm., *P., K., C.*

PARMELIACEAE.

Parmelia physodes Ach., *P., K.*
P. physodes var. tubulosa Mudd, *P.*
P. perlata Ach., *G., P., K., C.*
P. caperata Ach., *P., K.*
P. subaurifera Nyl., *C.*
P. saxatilis Ach., *S., P., K., C.*
P. saxatilis f. furfuracea Schaer., *P.*
P. sulcata Tayl., *P.*
P. dubia Tayl., *P., K.*
P. conspersa Ach., *S., K.*
P. Mougeottii Schaer., *S.*
P. exasperata Carroll, *P.*
P. fuliginosa Nyl., *S., P., K.*
P. fuliginosa var. laetevirens Nyl., *P., K.*
Cetraria glauca Ach., *P.*

USNACEAE.

Evernia prunastri Ach., *G., P., K., C.*
Ramalina calicaris Fr., *P., K.*
R. fraxinea Ach., *P.*
R. fastigiata Ach., *P., K., C.*
R. farinacea Ach., *P., K.*
Usnea florida Web., *P., K.*
U. florida var. hirta Ach., *P.*

PHYSCIACEAE.

Xanthoria parietina Th. Fr., *G., S., P., K., C.*
X. lychnea Th. Fr., *S.*
Placodium callopismum Mer., *C.*
Pl. murorum DC., *S., P., C.*
Pl. cirrochroum Hepp, *C.*
Pl. citrinum Anzi, *S., P., C.*
Pl. incrustans A. L. Sm., *S., C.*
Pl. aurantiacum Anzi, ?
Pl. pyraceum Anzi, *S.*
Pl. ochraceum Anzi, *C.*
Pl. vitellinulum A. L. Sm., *S.*
Pl. ferrugineum Hepp var. festivum A. L. Sm., *S.*
Pl. rupestre Branth. & Rostr., *S., P., C.*

Candelariella vitellina Muell-Arg., *S.*
C. epixantha A. L. Sm., *S.*
Physcia pulverulenta Nyl., *P.*
Ph. stellaris Nyl., *P.*, *K.*
Ph. hispida Tuckerm., *G.*, *P.*, *K.*, *C.*
Ph. tribacia Nyl., *K.*
Ph. orbicularis Dalla Torre & Sarnth., *P.*, *K.*
Ph. orbicularis var. virella Dalla Torre & Sarnth., *K.*
Rinodina demissa Arn., *S.*
R. sophodes Th. Fr., *P.*

LECANORACEAE.

Lecanora subfusca Ach., *G.*, *P.*, *K.*
L. subfusca var. chlarona Ach., *P.*, *K.*
L. subfusca var. allophana Ach., *G.*, *P.*, *C.*
L. rugosa Nyl., *K.*
L. campestris B. de Lesd., *S.*, *C.*
L. gangaleoides Nyl., *S.*
L. atra Ach., *S.*, *K.*
L. Hageni Ach., *G.*, *P.*
L. crenulata Nyl., *S.*
L. pallida Schaer., *K.*
L. carpinea Wain., *P.*
L. galactina Ach., *S.*, *C.*
L. urbana Nyl., *C.*
L. varia Ach., *G.*
L. farinaria Borr., *G.*, *P.*
L. symmictera Nyl., *G.*
L. polytropa Schaer., *S.*, *P.*
L. tartarea Ach., *S.*, *P.*
L. parella Ach., *S.*, *P.*, *K.*
L. calcarea Sommerf., *C.*
L. calcarea var. contorta Hepp, *C.*
L. calcarea var. Hoffmanni Sommerf., *C.*
L. gibbosa Nyl., *S.*
Acarospora smaragdula Massal., *S.*
L. albariella A. L. Sm., *K.*
Icmadophila ericetorum A. Zahlbr., *S.*
Haematomma ventosum Massal., *S.*
H. coccineum Koerb., *S.*

PERTUSARIACEAE.

Pertusaria velata Nyl., *P.*
P. globulifera Nyl., *P.*
P. faginea Leight., *P.*
P. multipunctata Nyl., *P.*
P. pertusa Dalla Torre & Sarnth., *S.*, *P.*, *K.*
P. ceuthocarpa Turn. & Borr., *S.*
P. leioplaca Schaer., *P.*, *K.*
P. Wulfenii DC., *P.*, *K.*

THELOTREMACEAE.

Thelotrema lepadinum Ach., *P.*, *K.*
Diploschistes scruposus Norm., *S.*, *P.*

CLADONIACEAE.

Baeomyces rufus DC., *P.*
Cladonia pyxidata Hoffm., *P.*
C. fimbriata Fr. var. simplex Wain., *P.*
C. cervicornis Schaer., *P.*
C. cornuta Fr., *P.*
C. subsquamosa Nyl., *P.*
C. parasitica Hoffm., *C.*
C. coccifera Willd., *S.*, *P.*
C. macilenta Hoffm., *S.*

LECIDEACEAE.

Gyalecta exanthematica Fr., *C.*
G. Flotovii Koerb., *K.*
Lecidea mutabilis Fée, *P.*
L. Metzleri Th. Fr., *C.*
L. ochracea Wedd., *C.*
L. dubia Hook., *G.*, *C.*
L. parasema Ach., *G.*, *P.*, *K.*, *C.*
L. goniophila Schaer., *P.*
L. leucophaea Nyl., *S.*
L. rivulosa Ach., *S.*, *P.*
L. albocoerulescens Ach., *P.*
L. sorediza Nyl., *S.*
L. confluens Ach., *S.*
L. contigua Fr., *P.*
L. contigua var. platycarpa Fr., *P.*
Biatorella flava A. L. Sm., *P.*
B. privigna A. L. Sm., *S.*, *C.*
B. pruinosa Mudd, *C.*
B. simplex Br. & Rostr., *C.*
Biatorina Bouteillei Arn., *C*
B. lutea Arn., *K.*
B. diluta Th. Fr., *C.*
B. lenticularis Koerb., *P.*, *K.*, *C.*
B. lenticularis var. erubescens Koerb., *C.*
B. chalybeia Mudd, *S.*
B. graniformis A. L. Sm., *K.*
Bacidea luteola Mudd, *K.*
B. phacodes Koerb., *K.*
B. umbrina Branth. & Rostr., *S.*
Buellia canescens de Not., *P.*, *K.*, *C.*
B. myriocarpa Mudd, *G.*, *P.*, *K.*
B. spuria Koerb., *S.*
Leciographa parasitica Massal., *P.* on Pertusaria pertusa.
Rhizocarpon geographicum DC., *S.*
R. calcareum Th. Fr., *C.*
R. petraeum Massal., *S.*, *P.*
R. alboatrum Th. Fr., *S.*
R. confervoides DC., *G.*, *P.*

LECANACTACEAE.

Lecanactis abietina Koerb., *P.*

ARTHONIACEAE.

Arthonia gregaria Koerb., *C.*
A. gregaria var. kermesina A. L. Sm., *C.*
A. astroidea Ach., *P.*, *K.*
A. radiata Ach., *S.*, *P.*

GRAPHIDACEAE.

Ophegrapha herpetica Ach., *P.*, *K.*, *C.*
O. atra Pers., *G.*, *P.*, *K.*, *C.*
O. vulgata Ach., *G.*, *P.*, *K.*, *C.*
O. varia Pers., *K.*
Graphis elegans Ach., *K.*
G. scripta Ach., *P.*, *K.*, *C.*
G. scripta var. pulverulenta Ach., *P.*
Phaeographis inusta Muell.-Arg., *G.*, *K.*
P. dendritica Muell.-Arg., *K.*
Graphina anguina Muell.-Arg., *P.*, *K.*
G. inustula A. L. Sm. (On holly), *K.*

CHIODECTONACEAE.

Enterographa crassa Fée, *P.*, *K.*, *C.*

DERMATOCARPACEAE.

Dermatocarpon miniatum Th. Fr., *C.*

VERRUCARIACEAE.

Verrucaria aethiobola Wahlenb., *S.*
V. submersa Schaer., *G.*
V. papillosa Ach., *G.*
V. nigrescens Pers., *G.*, *S.*, *P.*, *C.*
V. coerulea DC., *C.*
V. glaucina Ach., *C.*
V. fuscella Ach., *G.*
V. maculiformis Kremph., *C.*
V. Dufourii DC., *C.*
V. muralis Ach., *S.*, *P.*
V. rupestris Schrad., *P.*, *C.*
V. rupestris var. subalbicans Mudd, *C.*
V. integra Carroll, *G.*, *S.*, *C.*
V. parva Deakin, *C.*
V. calciseda DC., *C.*
Thelidium incavatum Mudd, *C.*

PYRENULACEAE.

Acrocordia gemmata Koerb., *K.*, *C.*
A. biformis Oliv., *G.*, *C.*
A. epipolaea A. L. Sm., *C.*
Arthopyrenia epidermidis Mudd, *K.*
A. punctiformis Arn., *K.*
A. cinereopruinosa Koerb., *G.*, *C.*
A. fallax Arn. (On cherry), *K.*, *C.*
Microthelia micula Flot., *K.*
Porina carpinea A. Zahlbr., *K.*
P. chlorotica Wainio, *G.*, *P.*
P. olivacea A. L. Sm., *K.*
Pyrenula nitida Ach., *G.*, *K.*

MYCETOZOA OF THE DUBLIN FORAY.

By G. Lister.

The weather during the first half of September was fine and dry, and the rain that fell just before and during the Foray was too recent to provide the best conditions for the appearance of Mycetozoa. Twenty-seven species were obtained, two of which were new records for Ireland, and three were new to the sub-province "L. 2" of Leinster, which includes counties Wicklow, Dublin and Kildare, Queen's County and King's County.

The first day's expedition to Powerscourt Demesne was wet. A large sawdust heap formed of coniferous wood yielded abundance of *Cribraria piriformis*, a species not before recorded for Ireland: besides the troops of mature red-brown sporangia, which exactly matched the colour of the sawdust, was much of the slate-grey or blackish plasmodium. On the same heap were numerous aethalia, mature and immature, of *Lycogala epidendrum*, the coral-red veins of plasmodium could be traced half an inch down among the sawdust. On fallen oak wood, amongst grass, *Arcyria pomiformis* was found, a new record for L. 2. The afternoon of September 24th, spent on Howth, yielded only *Didymium squamulosum* and *D. Clavus*, the latter being new to L. 2. The expedition to the Carton Demesne was more repaying to the hunters for Mycetozoa. In woodland among moist herbage were many old stumps and logs, where besides

Badhamia panicea, Trichia decipiens, Hemitrichia clavata, Perichaena corticalis, etc., a large growth of *Trichia contorta* var. *inconspicua* was found, a new record for L. 2. September 26th was also wet, but the excursion to Kilruddery was distinguished by the discovery of *Lachnobolus congestus*, a new record for Ireland.

In the following list *P.* = Powerscourt., *H.* = Howth, *C.* = Carton, and *K.* = Kilruddery.

Ceratiomyxa fruticulosa (Muell.) Macbr., *C.*
Badhamia panicea (Fries) Rost., *C.*
Physarum nutans Pers., *C.*
Fuligo septica (L.) Gmel., *P.*
Didymium difforme (Pers.) Duby., *K.* D. Clavus (Alb. & Schw.) Rost., *H.* D. squamulosum (Alb. & Schw.) Fries, *H.*, *C.*
Stemonitis fusca Roth, *P.*, *C.* S. hyperopta Meylan, *P.* S. splendens Rost. var. flaccida Lister, *P.*
Comatricha nigra (Pers.) Schroet., *C.*, *K.*
Cribraria piriformis Schrad., *P.* C. vulgaris Schrad., *P.* C. argillacea Pers., *P.*
Tubifera ferruginosa (Batsch) Gmel., *P.*, *K.*
Reticularia Lycoperdon Bull., *P.*
Lycogala epidendrum (L.) Fries, *P.*
Trichia affinis de Bary, *K.* T. scabra Rost., *C.* T. varia Pers., *K.* T. decipiens (Pers.) Macbr., *C.* T. contorta (Ditm.) Rost. var. inconspicua Lister, *C.*
Hemitrichia clavata (Pers.) Rost., *C.*
Arcyria pomiformis (Leers) Rost., *P.* A. denudata (L.) Wettst., *P.* A. incarnata Pers., *P.*
Lachnobolus congestus (Somm.) Lister, *K.*
Perichaena corticalis (Batsch) Rost., *C.*

NOTES ON IRISH MYCETOZOA.

By G. Lister.

In 1912 a list of the Mycetozoa found in Ireland up to that date was given in Part 63 of the Clare Island Survey, where 64 species are recorded. Since then, search for Mycetozoa has been made in many parts of the country by experienced workers among whom Miss M. Rea, Mr and Mrs Stelfox and Mr W. F. Gunn have been most active. Papers dealing with the results of their observations have appeared from time to time in *The Irish Naturalist* and other journals*, from the perusal of which it may be gathered that only seeing eyes and favourable seasons are wanted to prove that Ireland is as rich in Mycetozoa as her neighbours. The recent visit of the British Mycological Society to County Dublin, and the work carried on since by Mr and Mrs Stelfox have led to further additions to the Irish list, which now stands at ninety-eight. Of these perhaps the most interest-

* M. D. Stelfox, "Myxomycetes from the Dingle Promontory," *Irish Naturalist*, xxiv, No. 2 (1915). M. D. Stelfox and M. W. Rea give a list of Myxomycetes from North Ireland, *Annual Report of Belfast Naturalists' Field Club*, Ser. II, vol. vii, No. 2 (1914–15). M. W. Rea and M. D. Stelfox "Some Records of Irish Mycetozoa," *Irish Naturalist*, xxvi, No. 4 (1917). W. F. Gunn, "Some Irish Mycetozoa," *Irish Naturalist*, xxviii, No. 4 (1919).

ing species is *Diderma lucidum*, reported before for Ireland, but not confirmed till it was found in some abundance on mossy rocks within the spray of the Dargle Waterfall, last October. This rare species with its bright orange-red sporangia on slender black stalks, has been only met with before, with certainty, from North Wales where it has been found repeatedly since its discovery there in 1860. Growing near it, Mr Stelfox also found *Diderma ochraceum* and *Lamproderma columbinum* var. *brevipes*, both new records for Ireland. Other Irish gatherings of special interest are *Physarum pulcherripes* and *P. brunneolum*, both obtained by Miss Rea in County Down; the former is known elsewhere only from the United States, *P. brunneolum* has a wider range, but, as far as hitherto noted, a very discontinuous one, having been found in Portugal, New South Wales, California and Chili.

The following species and varieties have been recorded from Ireland since the appearance of the Clare Island Survey:

Badhamia foliicola Lister, *B. macrocarpa* Rost., *B. nitens* Berk.
Physarum pulcherripes Peck, *P. murinum* Lister, *P. galbeum* Wing., *P. viride* Pers. var. *incanum* Lister, *P. pusillum* Lister, *P. brunneolum* (Phill.) Mass.
P. crateriforme Petch, *P. straminipes* Lister, *P. didermoides* Rost., *P. virescens* Ditm. var. *nitens* Lister.
Fuligo septica Gmel. var. *candida* R. E. Fries.
Craterium aureum Rost.
Diderma floriforme Pers., *D. lucidum* Berk. & Br., *D. ochraceum* G. F. Hoffm. (*D. globosum* Pers., which appears in an early list, has not been confirmed.)
Didymium difforme Link var. *comatum* Lister, *D. nigripes* Fr. var. *xanthopus*, Lister.
Stemonitis hyperopta Meylan, *S. splendens* Rost. var. *Webberi* and *flaccida*, *S. confluens*, *S. herbatica* Peck, *S. flavogenita* Jahn.
Comatricha nigra Schroet. var. *alta* Lister, *C. elegans* Lister.
Lamproderma columbinum Rost. var. *brevipes* G. Lister, *L. arcyrionema* Rost.
Brefeldia maxima Rost.
Cribraria piriformis Schrad., *C. tenella* Schrad.
Dictydium cancellatum Macbr. var. *fuscum* Lister.
Licea minima Fries.
Dictydiaethalium plumbeum Rost.
Liceopsis lobata Torrend.
Trichia favoginea Pers. (confirmed), *T. scabra* Rost., *T. contorta* Rost. var. *inconspicua*, *T. Botrytis* Pers. var. *munda* Lister, *T. floriformis* G. Lister.
Hemitrichia Vesparium Macbr. (*H. Serpula* Rost. unconfirmed).
Arcyria ferruginea Sauter, *A. incarnata* Pers. var. *fulgens* Lister, *A. pomiformis* Rost.
Lachnobolus congestus Lister.
Perichaena vermicularis Rost.
Dianema corticatum Lister.

PRESIDENTIAL ADDRESS.

By J. Ramsbottom, O.B.E., M.A., F.L.S.

THE TAXONOMY OF FUNGI*.

At the outset of my remarks I would wish to express my satisfaction that my fellow members should have considered me worthy of occupying the Presidential Chair in the year that has seen the first Imperial Botanical Conference. We all hope that as a direct result of the conference a closer union in future will exist between botanists at home and those overseas and I trust that our Society will take an active part in all such Imperial efforts with a view to carrying out our chief aim—the study of mycology in all its branches. International relations are not yet all that can be desired but we as mycologists will lose nothing at any future International Congress if we can point to efforts made to further to its greatest extent the study of mycology within the Empire.

Shortly after our last Annual Meeting our Society suffered a great loss by the death of Sir Henry Hawley. An amateur in the truest sense of the word he was busily engaged for several years in preparing a monograph of the British Pyrenomycetes: it is much to be regretted that his manuscript was not left in a sufficiently advanced state to be completed for publication.

In considering matter for an address I was faced with the usual problem of choosing between discoursing on some general aspect of our studies and devoting myself to attempting to get clear in my own mind certain more or less floating ideas on the branch of mycology with which I am mainly occupied. The characteristic of our Society most commented on is the extreme friendliness of its proceedings and in making the choice of *The Taxonomy of Fungi* I trust I shall not be accused of attempting to spread discord in our ranks nor of taking undue advantage of brief authority to make statements which, by a thoughtful foresight on the part of those wise people who first arranged these matters, cannot be the subject for open discussion.

The taxonomist in mycology may at one time have been above suspicion but during the last few decades his position has been repeatedly assailed. One of the most amusing aspects of many discussions is that systematists are supposed either to be all in absolute agreement or to differ so radically that no botanist of average intelligence can be expected to pay the slightest attention to their deliberations. The fact of the matter is that

* Delivered at Bettws-y-Coed, September 1924. The address was given as it stands except for a few verbal alterations and the addition of the footnotes.

there is just the same agreement and disagreement among systematists as among physiologists, cytologists, anatomists, or even, to come a little nearer home, phytopathologists.

As a systematist is traditionally an individual doomed to pass a secluded existence in a herbarium it may perhaps not be amiss first to consider such an institution.

The word herbarium apparently does not now hold the honoured position it did formerly. In the last half century its prestige was usurped by the laboratory which in turn seems to be giving way to that somewhat vague entity known as the "field." Much credit is due to the band of young botanists of the latter half of the nineteenth century who, fired with the teaching they had received in German laboratories, revolutionised botanical teaching in this country. It can truthfully be said, however, that their influence has not been wholly for good. The time was when systematic botany was so neglected in most of our Universities that it was not considered necessary to be able to recognise any plant other than the few mis-called "types"—and these rarely in a living condition or even whole. A student was encouraged to construct phylogenetic trees and was *au fait* with all the most recent theories of evolution and the origin of species, but the identification of species or the study of specific differences was usually totally ignored. The great value of the introduction of the study of ecology into the Universities has been that students have been driven to consider plants as they grow. It is to be hoped that the time is not far distant when a graduate on leaving a university will not feel that he cannot make original contributions to botanical science on account of not having an up-to-date laboratory at his disposal and spirit material of the rhizome of some tropical plant: there is much interesting work to be done *e.g.* in mycology, for which merely the outlines of methods and the necessary standard works need to be indicated. The day of the amateur, trained or not, is far from over.

A herbarium, or, as it was formerly called *Hortus siccus*, is a collection of dried plants; named plants arranged on some system. The use of such a collection in most groups is obvious and it may be said that the ordinary herbarium methods of drying and mounting are more or less satisfactory for fungi with the exception of fleshy agarics and some of the saprophytic filamentous forms. The drawback, of course, is that herbarium plants cannot be studied in a living condition. A herbarium is purely and simply a convenience. Certain facts of structure may be made out from properly dried specimens almost as well as from fresh material, but such specimens have their limitations.

Let us first consider the arrangement of the specimens in a

herbarium. In my opinion the chief desideratum about an arrangement is that it should be the most convenient one. If an alphabetical or a numerical arrangement proved to be the most satisfactory there would not be the slightest reason against adopting it. As a matter of fact most mycological herbaria are arranged by Saccardo's *Sylloge Fungorum*. This work is used because it contains (or is reputed to contain) all the species* of fungi described up to 1910–11†. Many students taught on the Engler-Prantl System, or even on more modern lines, are surprised when a genus or species in which they are interested is not to be found in what is thought to be its natural position. Saccardo's classification is doubtless artificial and does not take into account the various rearrangements which research suggests would more nearly represent a natural order. Engler and Prantl's on the other hand was supposed to arrange the various genera according to their natural affinities and the second edition which is promised in three volumes, one of which is to appear in each of the next three years, will doubtless show many radical rearrangements. It is obvious, however, that a herbarium cannot repeatedly be disorganised in order to show continuous change in ideas—particularly when there is not always unanimity concerning the validity of the suggestions. The main point, however, is that no work other than Saccardo's attempts anything like a complete enumeration of species. The *Sylloge* has very many uses in a herbarium but the chief one is as an index. Mycologists are indeed in a fortunate position in having such a compilation for, on account of the enormous number of descriptions scattered in every type of publication, the life of a general systematist would otherwise be even less enviable than most people imagine it to be. Since the last volume (XXII) appeared the number of proposed new species seems to be increasing in geometrical progression and it is much to be desired that the promised continuation of this monumental work, which is really a complete mycological flora, will not be long delayed†.

To understand the working of a herbarium it is necessary to realise that there are two classifications—a classification of convenience which enables one to find a given specimen‡ with the greatest ease, and a theoretical one which aims at arranging

* This holds for all ranks. Consequently it is important that it should be realised more generally that a new genus obtains no mention in the *Sylloge* if it is based on one or more species whose descriptions have already been given. It is not sufficient, therefore, to rely on the generic indexes of this work when wishing to evade the perpetration of homonyms.

† A further volume of the *Sylloge* appeared in 1925, the first of three which are designed to include species described up to 1920.

‡ Or name a given specimen; cf. artificial keys.

plants according to their affinities. It may be pointed out that it was not until the time of Linnaeus that it was recognised that an arrangement of convenience was not necessarily the natural one.

In the same way as there are two kinds of classification there are two kinds of species*—taxonomic and natural. It is much simpler to define the first than the second but as a rule the two are not kept sufficiently distinct for obvious reasons. Systematic biology postulates the existence of natural species. The attempt to describe these gives the theoretical species of the systematist†.

Let us consider the naming of a specimen. On examination it is seen to be, say, an *Ascobolus*. The usual floras are consulted and no description is found there into which the characters will "fit" as we say, *i.e.* no description can be found giving the details of our specimen. Saccardo's *Sylloge* is gone through with no success and similarly the various periodicals which have appeared since the last volume of the *Sylloge*. The fungus does not agree with the description of any known species of *Ascobolus*. It is a "new species." (Though it is not what I am aiming at I might add, parenthetically, that there is no glamour about a new species—a new species is merely an organism of which no description can be found.) Now, having such a fungus, the usual custom is to describe it, *i.e.* draw up a diagnosis of what one considers the essential characters‡.

All specimens that agree with the details of a properly drawn up diagnosis comprise a species from a taxonomic point of view. Further knowledge may lead to the description being emended: the taxonomic species thus changes. The ideal aimed at, of course, is so to define our taxonomic species that they agree absolutely with natural species, but for clarity it is essential that the two concepts should be kept distinct. It is the changing of the

* I would express my indebtedness to my colleague Mr A. J. Wilmott for several of the ideas here put forward. It is not possible to say at this date which of them are definitely his, but I wish to put on record my appreciation of the benefits I have derived from discussions we have had on matters of nomenclature and classification during fifteen years as colleagues and friends in the Botanical Department of the British Museum.

† Mr C. Tate Regan in his Presidential Address to Section D—Zoology, at the British Association, Southampton (1925), gave a definition of a species which is interesting from this point of view. "A species is a community, or a number of related communities, whose distinctive morphological characters are, in the opinion of a competent systematist sufficiently definite to entitle it, or them, to a specific name." By a community is meant "a number of similar individuals that live together and breed together": an attempt to explain what a competent systematist is, within the meaning of the definition, would have been of interest.

‡ A concise diagnosis is much preferable to the wordy descriptions which cover pages of text, and usually succeed in leaving the reader as perplexed as the writer.

boundaries of taxonomic species which leads to much confusion of thought quite apart from the well-known "lumping" and "splitting."

My friend Mr C. G. Lloyd has for many years had a fling at what he calls "advertisements" but which most of us call authorities. Doubtless many systematists are misguided—or shall we say human—enough to like to see their name, or sufficient of it to ensure recognition, appended to a generic or specific name, and possibly also claim credit for what is colloquially called "making a new species." But the describing of new forms is not the work of a closed corporation indulging in back-scratching. The authority helps to precise the name. As everyone knows there are rules of priority and the general assumption is that a name can only mean one organism: if the same name is proposed later for a different species or genus it is a homonym and is invalid, *e.g.* if *Septoriopsis* Fragoso and Paul 1915, *Septoriopsis* Stevens and Dalbey 1917 and *Septoriopsis* von Hoehn. 1920 signify valid genera *Septoriopsis* must be used in the sense Fragoso and Paul used it and other names must be coined for the later genera. At present other names have not been proposed* but in any event the addition of the authority precises the meaning. Systematic mycology does not remain stationary however. In the attempt to make taxonomic species agree more closely with natural ones diagnoses are frequently emended by addition or subtraction. Even systematists do not always refer to an original description but take their definition from some modern work. As an example, if one is naming British Pyrenomycetes one would probably use Winter's monograph in Rabenhorst's *Kryptogamen-Flora*. A description being found which sufficiently fits the characters of the fungus the name and authority there given would be used without consulting the original diagnosis. Now the original diagnosis may be one that would not include the given specimen—or, on the other hand, may include many modern species. In my opinion the name of the fungus should have attached to it some indication of the source of identification if the original diagnosis has not been consulted. Let us suppose a *Clavaria* is to be identified: in Cotton and Wakefield's monograph, Rea's *British Basidiomycetae* and Coker's *The Clavarias of the United States and Canada*, several names, *e.g. C. cristata*, have a different significance. Is it not reasonable to say which diagnosis is being followed? A further point is that an author himself may emend his original diagnosis. For instance we cannot assume that from 1814 to 1877 in years of continuous research the illustrious Fries did

* Since this was written Petrak (*Ann. Mycol.* XXIII, 1925, p. 69) has proposed the name *Cercoseptoria* for *Septoriopsis* Stevens and Dalbey.

not alter his ideas regarding very many species and genera. For exactness therefore we should say which of his descriptions has been used.

Whatever a species may be we have something definite in a description but it must not be the description after it has been through the vicissitudes of a century's mangling. That this cannot be regarded as a matter of indifference to laboratory workers may be seen by a consideration of *Humaria rutilans* studied cytologically by Guilliermond and by Fraser. There is some doubt concerning what *Peziza rutilans* Fr. really is and the differences of opinion have led to a totally different interpretation in Rabenhorst's *Kryptogamen-Flora* and in Massee's *Fungus Flora*. Miss Fraser fortunately took the usual continental view of this species and so a controversy about the nuclear phenomena in the ascus was restricted to interpretation of facts and not adulterated with a discussion as to personal veracity.

If the statement be made that such and such an interpretation of a name is followed one factor causing discrepancy in results tends to be eliminated. The casual identification of an organism which has been investigated for several months is far more usual than many would imagine, and cannot be too strongly deprecated. Taxonomists are particularly interested in species which have been thoroughly investigated for reasons which I shall consider later. As a practical course I would suggest that when an authority is given this should mean that the original diagnosis has been followed and this may be precised by quoting volume, page and date. If a more recent diagnosis be used the emending authority should be added. Most workers rely mainly on a certain work and so long as it is known what this is we can ask for nothing more exact. A list of Agarics for example, becomes much more intelligible if a note is added saying that Rea's *British Basidiomycetae* is followed and any deviations from this indicated.

Having precised a diagnosis we have something certain—but we may not know what it means. However, in describing a new species an author is usually basing his description on a certain specimen or specimens, and may give a drawing. The fact that examples are known in which there is no agreement between the three complicates matters but the application of a name in that case is purely a question of nomenclature. Now nomenclature has probably a worse reputation than any other branch of a systematist's work; name changing, or as Lloyd more graphically expresses it, "name-juggling" is popularly supposed to be its object—"ici on lit les petites-affiches." The study of nomenclature has its fascinations—its chief requisite is a legal mind. Its aim should be to stabilise the names of plants so that when we use a name we have an idea of its significance.

What significance is to be given to a name from the point of view of nomenclature? Taxonomy abounds in uncertainties but there are a number of points where we are secure. One of these, if it exists, is the specimen or specimens used by an author in describing the species. For reason of greater certainty one specimen ought to be indicated by the proposer of the species as his type*. Then whatever range is given to the name that particular specimen is included: the name stands or falls by that specimen. This application of the type method has been extended by many systematists to genera also; there is a type species in a genus and throughout any changes made in the limits of that genus, the type species must remain. It seems to follow logically that the type of a genus depends ultimately on the type specimen of the genus. Type† is not a satisfactory word —a type specimen does not mean a typical specimen but the original specimen or one chosen in its place. Some of the disadvantages resulting from the neglect of adopting such a type method have recently been given by Shear in studying the genus *Phoma*. The International Rules of Botanical Nomenclature read: "When a genus is divided into two or more genera the name must be kept and given to one of the principal divisions." By this method, as the heterogeneity of the genus is realised, a number of species are taken away to form a new genus and the older name is retained for the major group: this goes on in some of the larger genera until a residue of imperfectly known species is left to bear a well-known name although it may contain no species which the author of the genus himself included. This "method of remainders" or "residue method" leads to much confusion.

It is fashionable to affect a humorous attitude towards nomenclature but it is a remarkable fact that when overseas botanists were circularised to submit suitable subjects for discussion at the Imperial Botanical Conference more suggested nomenclature than the remaining botanical subjects put together. Consequently a small sub-committee was formed to consider whether changes in the International Rules were desirable.

* The type concept is recognised in the International Rules of Botanical Nomenclature (1910). Article 39 Recommendation xviii *bis* reads: "When publishing names of new groups, one should indicate carefully the subdivision which one considers the nomenclatorial type of the group: the type genus of a family: the type species of a genus: the type variety or type specimen of a species. This precaution will avoid the nomenclatorial difficulties where, in the future, the group is to be divided." This is the translation given by Hitchcock in his *Descriptive Systematic Botany*, p. 159. Though he does not state that it differs from the "official" translation a comparison of the two reveals a difference in interpretation, which in this instance has been put into words.

† The name "standard" has been proposed by Sprague to replace type as it serves as a standard by which other specimens may be compared in case of doubt. It is not likely that this suggestion will be adopted as what is meant by type specimen and type method is well understood by systematists.

The following resolutions amongst others were adopted at the Conference:

1. Certain alterations should be made in the International Rules of Nomenclature.

2. Art. 36 (invalidating names of new genera published on and after January 1st, 1908, without Latin diagnoses) should be replaced by a strong *recommendation* to supply Latin diagnoses.

5. The principle of the type method of applying names should be formally accepted.

6. Art. 55, 2° (rejecting duplicating binomials, *e.g. Linaria Linaria*) should be revoked.

There were eight other resolutions and these will be brought forward as the agreed opinion of Empire Botanists at the next International Congress. Mr Sprague at our meeting in January of this year* went into several of these matters. My reason for referring to them here is to draw attention to the special needs of mycology. New genera are being described by the thousand, new species by the hundreds of thousands and new strains threaten to reach their millions. He who pays the piper calls the tune. Mycologists are now turning the handle of the species mill to such purpose that we ought to have a voice in drawing up Rules. The next International Congress is to be held in Ithaca in June 1926†, and by that time mycologists ought to have well considered their position. Such matters as the type method are general but we have special difficulties in applying it‡.

Moreover are we satisfied with the different starting points for different groups? At Brussels this was carried by 130 votes to 4 but after fourteen years' experience are we agreed that it would not be better to begin all mycological nomenclature with Persoon or even Linnaeus? There are many matters arising from the prevalence of pleomorphy some of which will be mentioned in the course of my remarks. All such difficulties should be brought forward for proper International consideration; it is surprising how discussion frequently leads to agreement or at least compromise.

We have now two definite things—a description and a type specimen (for of course the type method implies that there *must* be a type in existence; if the author has not chosen one it is better for his followers to denote one than to be eternally worrying about it). Taxonomy, however, is not concerned only in dealing with type specimens. We all of us are agreed that there are such things as natural species. Though unhappy with

* 1924.

† The date was afterwards altered to August. No decisions on nomenclature are, however, to be made.

‡ It will probably be necessary to modify the type method for certain groups of fungi.

Cortinarius each and every one of us would guarantee to spot *Amanita muscaria* and *Coprinus comatus* and have a good shot at such polymorphic forms as *Armillaria mellea* and *Laccaria laccata*.

The name, description and type specimen of a fungus are to be as exact as possible and the first two are to mean one thing and one alone. To identify various fungi, to group together and to alter descriptions until finally the taxonomic species really becomes that indefinable something we know and recognise in the field is one of the aims of taxonomy. And from a practical point of view a systematist endeavours to be able to give a name to any fungus in any condition. The other aim of taxonomy is to arrange genera and species into groups giving some idea of relation. Most systematists believe in evolution but though this hypothesis is the thread running through all modern schemes of classification taxonomic botany is not concerned with the how and wherefore. Systematists naturally have ideas on the subject of evolution seeing that they are constantly engaged in studying organisms but it does not seem to me that an attempt to solve the problem of the origin of species or of larger or smaller groups is the work of the taxonomist.

Every investigator in biology sooner or later hits up against matters of taxonomy. Frequently his first working acquaintance with the subject gives him rather a bad impression of it. It may be that he is interested in some special aspect of a problem. He may wish to identify a fungus which he has been investigating from some special point of view. He may realise that to say that an unnamed fungus does this, that or the other is not of very great use and therefore wishes to say definitely what the fungus is. As a result of his investigations he has found that his fungus takes on many forms, or produces some peculiar chemical compound, or has some strange property which, from his point of view, should enable one to name the fungus immediately. But the particular information he has acquired may be useless in affording one a clue to its identification: unless similar work has been done no hint can be given him*. In such cases the species should be described as new.

I am of the opinion, despite the many moanings to be heard, that we are better situated in mycology than are taxonomists in any other group of plants. There is an absolute jumble amongst fungi at present, far more so than when Linnaeus placed them in his class CHAOS. My reason for the statement is that we are

* A problem often encountered is that of naming a sterile mycelium in culture. Frequently this is a timber-destroying organism. A most useful piece of work would be the growing of all such destructive agents from the spores or sporophores and tabulating their cultural characters.

gaining so much information about fungi in general—morphology, cytology, pathogenicity, chemistry and cultural characters.

Though we are told that species when run to earth differ in chemical properties, or physico-chemical properties, or these with the addition of vital force, or entelechy, from a practical standpoint we are driven to define them, at least broadly, from their morphology.

Even the most rabid experimentalist describes the species he is studying from its morphological characters which is of itself significant. But are we to ignore characters other than morphological? Mycologists at least would be very unwise to do so. What we require is as much information as we can get, of any and every kind, concerning any given organism. In ordinary herbarium work it is not always possible to carry out certain lines of investigation which one feels might give a clue to affinities. If time were no object, or in other words, if sufficient systematists could be endowed to carry out research in pure taxonomy, no doubt something might be done in this direction but as the matter stands the systematist must cull information from where he can and there is no mycological writing but what may give a clue. One of the great hopes of the systematist is the phytopathologist. Perhaps he, of all others, has in the past had most to criticise in the present state of systematic mycology. The liason which exists in our society is, I am certain, one of the surest signs that both subjects will advance in this country. Probably more trained botanists are engaged on plant disease investigation than on any other branch of botany: one of the reasons for this is, of course, the fact that the subject is what is called economic, which may be interpreted as meaning that even a trained botanist must have some means of sustenance. When a disease is being investigated the object is, as in all disease, to find a means of prevention or of cure. Theoretically, the so-called host is the more important of the two or more organisms concerned—leaving the investigator out of account—but the parasite must be studied in all its aspects. From a purely systematic point of view all fungi are of equal importance but we are gradually obtaining information about parasitic fungi which will eventually change our whole ideas of classification. For some recondite reason systematists are assumed to lament this. At many of our meetings some new fact is presented which at first sight does not seem to fit into the scheme of things—but why should we deplore the addition to our knowledge of the chemistry or pathogenicity of a form? Much of it is good-natured banter but it cannot be stated too plainly that any investigator who adds in any way to our knowledge of any fungus is supplying facts which may be useful in taxonomy.

What is required is sufficient detail to be able to identify the species investigated—or give its name with certainty—both of these are pure taxonomy—and any additional information may give a clue to relationship.

Up to the present I have dealt only with species in the old sense so far as natural species have been mentioned. As a unit of description I have taken a taxonomic species. In several recent mycological papers the ideas given forth by Lotsy, in his *Evolution by means of hybridization*, have received approval. Lotsy writes: "He who ventures to write on the origin of species, ought to define what a species is, so ought he to do who describes species, no matter whether he considers his task finished when the description has been made, or whether he intends to make use of the described species to build up a more or less elaborate system. In other words: the systematist, as well as the evolutionist, ought to state clearly what he means by a species." This, which reads somewhat like an undergraduate's essay, is followed by three definitions. The first is that of a Linneon: "To replace the term species in the Linnean sense, and to designate a group of individuals which resemble one another more than they do any other individuals."

It is stated that "to establish a Linneon consequently requires careful morphological comparison only."

The term Jordanon is used "to replace the term species in the Jordanian sense, viz. mikrospecies, elementary species, etc. and to designate a group of externally alike individuals which all propagate their kind faithfully, under conditions excluding contamination by crossing with individuals belonging to other groups, as far as these external characters are concerned, with the only exception of noninheritable modifications of these characters, caused by the influences of the surroundings in the widest sense, to which these individuals or those composing the progeny may be exposed."

"To establish a Jordanon, morphological comparison alone consequently does not suffise; the transmittability of the characters by which the form was distinguished, must be proved by experimental breeding."

The term Species is used "to designate a group of individuals of identical constitution, unable to form more than one kind of gametes; all monogametic individuals of identical constitution consequently belong to one species."

"To establish a species, neither morphological comparison alone, nor experimental breeding by itself is sufficient, nor are the two combined; hybrid analysis is required in addition."

Such a definition of a species is not one that systematists will accept. The term has never previously been regarded as of such

a narrow connotation and if it is ever used in this sense it will need to have Lotsy's name added to it unless his advice is followed and we all define what we mean by species. A species is what Lotsy calls a Linneon but few, if any, would be satisfied in these days with such a parody of it as Lotsy's definition suggests.

The attempt to apply Lotsy's terminology to fungi has not been very happy. In this country Dr Brierley adopted what he called "perhaps the main features of this as they apply to fungi" and as he clearly stated many of the difficulties of systematic mycology received a certain amount of support. The Linneon and Jordanon are given in Lotsy's sense but when we reach the "species concept" we have a change which is not commented on, and leaves us at least no better placed than before. The name species is still used "to designate a group of individuals of identical constitution." If we could satisfy ourselves as to identical constitution, or even constitution, we should be a long way on our journey. I am uncertain whether Brierley's definition is intended to go beyond that sentence. The following sentences read: "To establish a species neither morphological comparison alone, nor comparison of the morphological facies of the organisms on standardised series of culture media is sufficient. Analysis of physiological reaction to standardised conditions is required in addition." This to my mind in no way helps us to gain a clear idea of any unit we are in search of, and seems no more practical for fungi than is Lotsy's idea of the necessity of hybridisation to establish a flowering plant species. We know there are groups below the old Linnean species but a consideration of these may be left for a few moments. What I wish to say now is that the statement frequently made that mycological systematists are satisfied with gross morphology shows a ludicrous lack of knowledge not only of taxonomy but also of mycology. We are in danger on the one hand of being carried away by the real species monger who litters up pages with new species—new in that he never troubles to ascertain what his predecessors, his contemporaries or even himself have done—and on the other by those who, having hardly ever succeeded in identifying a fungus, tell us in elegant periods covering an echoing emptiness that the old masters of botanical science if not frauds and mountebanks were at any rate fools.

So far as I am aware small attention has been paid to hybrids among fungi from a general point of view.

Apart from some original assertions from Sir John Hill—a person somewhat ingenious in all matters pertaining to the imagination—little or nothing was done until the epoch-making work of Blakeslee in 1904. It is true that Saccardo had pre-

viously recorded a supposed hybrid between *Nectria Desmazieri* and *Lisea Buxi*. The reputed parents were growing on a box twig and amongst them there were abundant perithecia having in their lower three-quarters the beautiful red tissue of the *Nectria*, while the rest, which contained the ostiole, showed the azure blue of the *Lisea*. Whatever the nature of the fusions such an occurrence deserves further study.

Blakeslee's work is sufficiently well known not to require detailed mention. He found that though in certain Mucoraceae, *e.g. Sporodinia*, a spore sown from a sporangium could give rise to zygospores, in others, such as *Rhizopus*, a single spore gave only sporangia. Two different strains were found in such forms, one of which was given the sign (+) and the other (−), and it was only when two strains of opposite signs (or sex) fused that zygospores were produced. Where the mycelia are similar the fungus is said to be homothallic, where a (+) and a (−) strain exist the fungus is heterothallic. Considerable work has been done on these lines in Mucoraceae in the last twenty years and at present certain controversies are in progress regarding the constancy of these strains. Blakeslee's original strains of *Rhizopus nigricans* have retained their characters through about two hundred and fifty generations but some investigators consider that a series of transitions exist between homothallic and heterothallic forms. Whatever the facts, there may be sufficient morphological differences between the (+) and (−) strains of the same fungus for them to have been described as separate species, whereas, on the other hand, in some species, there are considerable differences between the different races of a single sex. Saito and Naganishi have recorded a true hybrid zygospore between different species of *Mucor* but it seems uncertain that the forms they worked with were really different species. The possibility of the existence of such hybrids is, however, not to be lost sight of for it has been shown repeatedly that the opposite sexes of different species are capable of showing an imperfect sexual reaction when grown in contact. A race may react with the opposite sex of another species under temperature conditions which do not allow it to form zygospores with its normal mate in its own species. Thus *Cunninghamella** will readily give imperfect hybridisation reactions with species of *Mucor* at temperatures below 20° C. but will not itself form zygospores at so low a temperature; while some *Mucor* species are weak in reaction when contrasted *inter se*. The vigour of the reaction therefore has no necessary connection with the taxonomic relationships of the forms

* *Cunninghamella*, it may be remembered is so unlike the ordinary Mucoraceae that it was originally described as a Hyphomycete.

involved. What seems to follow from this is that there is something fundamental common to all the strains of one "sex."

Burgeff produced hermaphrodite mycelia by mechanically mixing the protoplasms of the vegetative mycelia of plus and minus strains of *Phycomyces*. Hermaphrodite zygospores were occasionally produced and scanty sporangia which soon gave plus and minus strains. Such mixochimeras, as he termed them, would probably disconcert others than systematists if they were found to occur naturally.

That attempts at what one might term illegal crossing may have unlooked-for results is shown by some further work of Burgeff on *Chaetocladium* and *Parasitella*. These are both parasitic on species of *Mucor*. Both form gall-cells which in the second genus becomes a thick-walled storage organ somewhat resembling an azygospore. The gall-cell contains protoplasm from both host and parasite. While both plus and minus strains of *Parasitella* parasitise both plus and minus strains of most *Mucor* species it was found that the plus strain of *Parasitella* would attack only the minus strain of *Absidia glauca* and conversely. It is suggested on this and other grounds that the parasitisim of *Chaetocladium* and *Parasitella* is a sexual process and has arisen as an attempt at hybridisation.

The knowledge of heterothallism has been extended very much during the last few years and is now known to occur in practically every fungus group—Phycomycetes (both Oomycetes and Zygomycetes), Ascomycetes (Pyrenomycetes, Discomycetes and probably in yeasts) and Basidiomycetes (Ustilagineae and Hymenomycetes). To consider the various aspects of the matter would take me too far from the subject of my address but Kniep's work on *Aleurodiscus polygonius* will suggest the complexity that faces us; it is surprising how frequently a clear-cut story becomes more and more puzzling as further research is accomplished; Kniep was able to study the behaviour of the four spores of a basidium in this species as they are shot off simultaneously. As was to be expected, assuming the four nuclear divisions in the basidium to be reduction divisions and that the so-called sex of the strain was dependent on its nuclei, two of the spores were of one sex, and two of the opposite sex. Only two strains were obtained from any basidium but when the mycelia from the whole fruit-body were analysed there were found to be four types or sexes. Vandendries is able to explain some complicated results in *Panaeolus separatus* on the assumption of four different sexes.

Brunswik's preliminary account of his work on *Coprinus* shows that the four spores of one basidium may give mycelia all of different sexes and that geographical races may occur.

A fact brought out by Kniep is that a single spore of *Schizophyllum commune* can furnish a fruit-body apparently indistinguishable from that formed by the union of two mycelia except that it does not possess clamp connections. This, at first sight, might appear to be of little interest to systematists, but are there not discrepancies in the accounts of the number of spores on the basidium, as *e.g.* in *Hygrophorus conicus*, where the yellow form has two spores and a uninucleate mycelium, which led Maire to propose the genus *Godfrinia* for its reception and other similar phenomena which may find their interpretation along these lines?

A point concerning heterothallism which has struck many mycologists is that we may have here some explanation of that bugbear to systematists, the Fungi Imperfecti. The assumption always has been that this group is a dumping ground for unattached conidial forms. Sometimes they have been defined as Fungi with incomplete life histories but a saner definition would be that they are Fungi concerning which our knowledge of their life cycles is incomplete. Very many of the Fungi Imperfecti have been joined up to their perfect stage in the past and suggestions of such relations are scattered throughout literature. It seems to me, however, that it is not unlikely that the reason many of them remain isolated is that they are heterothallic and few attempts have been made as yet to try the effect of different strains on one another. I am not suggesting that success will attend every effort but I do think that in such fungi as *Sepedonium chrysospermum, Bispora monilioides, Coryne sarcoides* and others—even *Penicillium**, where the conidial stage is remarkably common and the reputed perfect stage sometimes very rare—we might look for heterothallism. Whenever culture work on so-called pure lines or similar investigations are being carried out I would suggest that the strains should be tested against each other and the result stated, if negative; presumably we should have no cause for anxiety about a positive result being disregarded. It is quite conceivable that evolution has proceeded in conidial forms. Is it possible that in some instances it has resulted in a loss of sex? If the Fungi Imperfecti contain unrelatable conidial stages that is presumably what has happened, for in our present state of knowledge we must assume that they were homothallic or heterothallic originally. Such facts that *Cunninghamella echinata* forms abundant sporangia above and below 25° C., but only forms zygospores above that temperature, indicates some of the difficulties. The Fungi Imperfecti have always annoyed systematists and, moreover, being the cause of most fungus

* Dr Derx has proved *Penicillium luteum* to be heterothallic (see p. 107).

diseases, whether of plant or animal, and often being easy to culture have caused annoyance and despair in other circles. Academic mycologists as a rule utterly ignore them, a reasonable but not satisfactory procedure. The assumption in systematic mycology is that they form an artificial group and, as they do not possess a perfect stage, they have usually been classified in an appallingly artificial manner. Recently Vuillemin, von Hoehnel and others have attempted to instil a little more reason into their classification but at present the general belief is that a higher form may have conidial stages which are now placed in different conidial genera, and conversely that a given form-genus may be the conidial stage of more than one perfect form. With further knowledge of the relation between sexual and asexual stages the species of Fungi Imperfecti ought to be taken out of the group lock, stock and barrel and joined on to the perfect stage. It is only in this way that we can get rid of the idea that the Fungi Imperfecti form a group equivalent in rank to the other great groups*.

As I mentioned above Fungi Imperfecti have been much studied in laboratories for various reasons. It has long been known, indeed since the earliest times of culture work, that fungi grown on media are extremely liable to take on forms not met with under natural conditions. As a consequence the results of culture work did not appeal to those systematists who conducted it. Further investigations, such as those of Matruchot thirty years ago, showed that when certain media were used a fungus might have its facies so altered that by a systematist it would be placed in another genus. It is now one of the best known features of culture work that the form of a fungus can be altered in all sorts of ways by the use of different media. Much has been made of this from a theoretical point of view. A popular method of representing a species nowadays is to write a little equation where *a* = the genotype, *b* the environment and *ab* the phenotype. This is a very deceptive method of representation as it simulates mathematical exactness. Granting for the moment that "*a*," the genotype, is a constant —a peculiar assumption concerning a living and consequently constantly changing organism, what of *b* the environment? Every one is agreed that the environment of a plant growing

* As this stands it requires amplification. A natural classification would take note of conidial forms and treat them in connection with the perfect stage. A classification of convenience places conidial forms in form-genera in the Fungi Imperfecti. We might combine the two methods in our systematic works by uniting all stages of a fungus in one description and leaving the name of the imperfect stage or stages in the Fungi Imperfecti with cross references. It is not unlikely that with greater attention to the classification of the different sections of Fungi Imperfecti we shall gain much information concerning relationship.

under ordinary conditions would hardly be considered as a thing we know with any exactness. With a culture medium it is tacitly assumed that we have rigidly standardised conditions and might therefore with some hope of success begin to guess at that will o' the wisp "*a*." It is obviously possible to grow certain fungi in conditions that they are never likely to encounter in nature. Being able to bring about various alterations in the medium we are able to influence the growth of the fungus often in startling ways. But is ever such a medium constant? Potato, prune, and other natural substances are frequently used for media but it is beginning to be recognised that a synthetic medium is more likely to have a definite composition. We may know the composition of the agar we use and the exact percentages of the various chemicals before the medium is sterilised, we may assume that sterilisation always brings about the same changes, but does the medium remain constant when a fungus has begun to grow upon it? Often the change in the medium is visible to the naked eye and we know that staling products are poured out. A freshly made up medium differs often to a great extent from one which is a week old, and the humidity in a tube or Petri dish varies in amount. The only factors that can be regulated with certainty are probably temperature and light intensity.

A comparison of the growths of the two strains of a heterothallic species with what occurs on the same medium when both are present, and the comparison of the growth under the same conditions of a starved mycelium and one which has had a happier past would convince most mycologists that the mathematics of these things is more of the Einstein type than of the Hall and Stevens*. What is always with us however is the *ab* and in the present state of knowledge we can hope for little more than to define this morphologically. Is it too much to ask that when an investigator is working with a fungus that can be cultivated he should, where possible, run his fungus through a few of the more common media and give data of the results? Almost every worker either modifies someone else's medium or makes up a fresh one—media-mongering is becoming as prevalent as species-mongering—and with the very best intentions it is not always possible to make up extravagant media; and so one does what one has to do with diagnoses in Russian and Japanese. In bacteriology, which, owing to the size of the organisms with which it is concerned, cannot gain much from morphology but has to define its species to a great extent from cultural characters, the Society of American Bacteriologists

* Perhaps it should be explained that the Hall and Stevens mentioned are the authors of well-known English text-books of elementary mathematics.

has drawn up a descriptive chart after the method of the Dewey decimal system. No such method has yet been advocated for fungi. Lutz and Guéguen, however, read a paper at the International Congress of Botanists at Paris, 1900, suggesting that some scheme similar to one just previously proposed by Grimbert for bacteria should be applied to Mucedineae and yeasts. They proposed Raulin's solution as a standard medium and gave details of the preparation of fifteen modifications of this solution—also milk, potato, carrot and egg albumen. They even entered so far into details as to suggest the use of Erlenmeyer flasks, but the scheme appears to have appealed to none.

In 1908 Mangin investigated species of *Aspergillus* in culture. Struck with the state of affairs in that genus he suggested that the matter should be discussed by the mycologists at the Brussels Congress though I cannot find that this was done. His suggestion was that the diagnoses of species which could be grown in culture should be established as far as possible on the characters at the optimum of growth, they should be accompanied by temperature data and an indication of the amplitudes of variation according to the conditions of the medium. I should like to suggest that at the next International Botanical Congress a very appropriate subject for discussion would be that of the best methods of precising diagnoses drawn up from cultures.

Another matter that might also be discussed with advantage is the nomenclature of ranks lower than variety. The special forms or biological races in Rust Fungi were considered to some extent at the last International Botanical Congress but matters have become rather more complicated since. The older view is well represented by Fischer, who accepted as species: (1) all forms that are structurally distinct; (2) all forms which have a different life cycle; (3) all forms which differ in their host plants in as far as the hosts belong to different genera; in heteroecious rusts species are recognised if one generation, aecidia, uredo or teleuto occurs on different genera of hosts.

The work accomplished, during the last year or two, principally in America, has shown that such a comparatively simple method of nomenclature is insufficient for practical purposes—and the essentials of nomenclature are that it should be practical and practicable. As an example of the present state of our knowledge *Puccinia graminis* var. *Tritici* may be taken. This consists of at least thirty-seven biological forms which can be distinguished readily from each other by their action on certain pure-line varieties of various strains of *Triticum*. Stakman states that "the longer one works with these forms, the deeper becomes the conviction that they represent as real, as constant, and as genetically pure entities as do morphological species."

The work of Klebahn, Stakman and others has shown, however, that such physiological species frequently exhibit morphological differences. The forms of *Puccinia graminis*, which are separable on the basis of their action on different genera of host plants, can be recognised by the size, shape and colour of the uredospores and also by the size of the teleutospores and aecidiospores provided these spores are developed on hosts of the same approximate degree of susceptibility, and under identical environmental conditions.

Work on Peronosporaceae has yielded similar results: Gäumann has recognised more than fifty such forms of *Peronospora parasitica* occurring on members of the Cruciferae. It may well be that such forms exist in many, if not all, parasitic groups. Their definition depends mainly upon the susceptibility of the different strains of host plant; it being assumed, on the evidence so far accumulated, that this susceptibility is constant under definite environmental conditions. The host therefore acts as a selective medium and we can compare this with Dox's results in *Penicillium* and *Aspergillus*, where it was found that some species can be recognised more easily by their effects on certain media than by morphological characters.

Single-spore cultures have shown that many species consist of a number of strains or pure lines. Such strains have long been known in yeasts, principally through the work of Will, but within recent years the work of Johannsen on pure lines has attracted workers in every branch of biology, and fungi, fortunately, have not escaped. The saprophytes capable of culture are attracting attention and as the experiments are easy to carry out we may hope for a rapid accumulation of data from post-graduate students. One of the conclusions of La Rue and Bartlett shows what we may expect. "It appears that by using a sufficiently refined technique a nominal species such as *Pestalozzia Guepini* might be resolved into an indefinite number of demonstrably distinct strains, the number depending only upon the precision of the methods." A further statement by these authors reads: "The species concept in the Fungi Imperfecti is of necessity a highly artificial one. The ultimate unit, an impracticable one for purposes of classification, is the pure line descended from a single spore." The treatment of such pure lines from a taxonomic standpoint depends upon whether they are indefinite in number or not: if they are indefinite we may ignore them, as for all practical purposes of classification they would be the same as individuals. (Incidentally one might ask whether we are quite sure what constitutes an individual in many fungi.)

What are loosely termed "mutations" are recorded by many

of the older writers. However, practically all workers on pure lines report permanent changes which occur either infrequently, as in *Pestalozzia* and *Mucor*, or commonly, as Stevens has recorded in *Helminthosporium* and Brown and Horne in *Fusarium*. It has been held by some that because no nuclear change is known to occur in the production of these forms they cannot be spoken of as mutants. Whatever we call them they occur and are frequently permanent *. We know little or nothing more about them. Do they occur in nature or is growing a fungus in a culture medium to be compared with growing a wild plant in a flower bed? Personally I can gain no mental satisfaction in regarding protoplasm for one purpose as an extremely stable chemical compound differing in different species in some small constituent but unchangeable through the ages no matter to what conditions of life the organism is subjected, and for some other purpose regarding it as a very welter of colloidal chemistry. If there are differences in the mode of origin of saltations these may be useful in enabling us to distinguish different types and to assign to them different ranks.

What is to be done with these various categories? We have the ordinary systematic species at one time defined on purely morphological grounds for the sole reason that no other method was then possible. These must still remain the unit of classification—and however the physico-chemical advocates bemoan the fact they will still have to record their results in *Pestalozzia Guepini*, for example, or in *Sterigmatocystis niger*. Such species should, however, be precised in every possible way—whether the precision comes from chemical, physiological, anatomical, cytological, cultural or any other characters. Lumping and splitting are purely temperamental, but splitters will group their elementary species in some such way as Costantin and Lucat did the closely related species of *Aspergillus* of the *fumigatus* group for which they used Chauvaud's term stirpe.

Below the rank of species various grades are listed in the International Rules, subspecies, variety, subvariety and what not, which may, or may not, have their uses in mycology: most of them seem redundant and to depend for their definition on personal idiosyncrasy. Biological species should be given definite names, the rank depending upon whether both morphological and physiological characters are present or physiological ones alone. In this way we should be able to speak of them, but for clarity the systematic species into which they fall should be indicated. Pure lines with definite morphological or physiological characters require to be considered fully when we have

* Their permanence is sometimes only relative depending upon the cultural methods adopted as *e.g.* Chaudhuri found in *Colletotrichum biologicum*.

more information as to their prevalence and importance from a practical point of view. It may be that, like cultivated flowering plants, they require names. Whatever we do I hope that such nomenclature as "*Torula anomala* x's strain No. 1" will not be considered legitimate, although it is in essence the system adopted in Horticulture with its Madame Butterfly's and Potato Queens.

For saltants we should have a separate rank, regarding them as forms of the species from which they are found to have arisen and noting whether they are known in culture only. Their prevalency and permanency must decide their taxonomic treatment.

Taxonomy is—even over the ground to which I have restricted myself—a controversial subject, but taxonomists, even when they happen to be mycologists, claim that they are botanists. Botanists in these matters have a reputation which they must not besmirch.

Alphonse de Candolle, in his classical work *La Phytographie*, writes: "All science, including botany, elevates the character in that it requires an ardent love of truth and rests on the idea that authors are thoroughly truthful. Science in this world plays the part of a practical school of good faith. Following these reflections one can regard botanists as being ordinarily and of necessity always men of peace, inoffensive, indulgent of the mistakes of their colleagues, and occupied more with the advancement of science than with their own interests or petty distinctions."

So speaks a botanist, but he is not alone in his opinions. R. L. Stevenson tells us that "men who fish, botanise, work with the turning-lathe, or gather seaweeds, will make admirable husbands; and a little amateur painting in water-colour shows the innocent and quiet mind."

So liberally endowed by providence, it ought not to be beyond our powers of restraint to work in such unity that we may bring nearer to accomplishment the ideal of Asa Gray—"Botanical classification, when complete, and correct, will be an epitome of our knowledge of plants."

LICHEN DYES.

By A. Lorrain Smith.

Lichens are peculiar plants in that they are composite organisms formed of fungal hyphae and green or blue-green algae that live in symbiotic relationship, each partner or symbiont contributing to the other and to the general good of the whole plant the material necessary for life and development.

The dual life has been curiously successful: lichens are all thalloid plants and no great development on morphological lines has been reached, but structural adaptations of various kinds have been formed to meet the necessities of their growth. They have spread everywhere over the earth's surface: they grow freely in the tropics; they reach almost to the poles, where they flourish on any bare rock, and they have reached higher up the mountains than any other vegetation. This power of meeting all conditions is directly due to their composite nature; but another of their most striking peculiarities is the formation within their tissues of organic substances—lichen-acids—some of which yield brilliant colours and are used to dye the animal fibres silk and wool. They have also been employed in colouring marble and rubber goods and for staining bacteria.

Acid substances occur in lichens that are associated with bright green algae and usually in well-aerated and well-lighted parts of the plant. They are not produced by lichens in which the algal symbiont is blue-green (Collemaceae, etc.), though a substance peltigerin has been extracted from *Peltigera canina*, a blue-green species. Much work has been done by chemists on lichen acids and in 1907 Zopf published the results up to that date—a record of about 150 different kinds of which the properties and chemical formulae had been determined. The work still proceeds: Lettau, for instance, in 1914, recorded the presence of salazinic acid in 70 different lichens.

These peculiar substances, so far as known, are only found in lichens. An almost similar body occurring in rhubarb root, called chrysophanic acid was supposed to be identical with parietin, the yellow colour-substance of *Xanthoria parietina* and allied species, but the chemical formula is different.

The use of these lichen-acids as a dyeing industry dates to a remote age. It is supposed that Ezekiel referred to garments dyed with lichens when he denounced the luxury of Tyre: "blue and purple from the isles of Elishah was that which covered thee." Theophrastos and Pliny almost certainly indicated a lichen in the Phycos Thalassion, "with crisp leaves used in Crete for dyeing garments." The Phycos Thalassion of the Greeks is undoubtedly the lichen *Roccella* which grows on rocks by the sea. Its use as a dye substance came from the East to Greece and to Italy; afterwards the art seems to have been lost, then rediscovered in the fourteenth century by a Florentine merchant, Roderigo, who made a large fortune and founded the family of the Orcellarii or Rucellai, hence possibly the name *Roccella*, and the derivation of orchil.

The beautiful blue orchil dye is the most renowned and the most prized of all the lichen dyes, and in different countries has

been known as orseille (France), litmus (Holland), and cudbear (Scotland). The lichens from which it is extracted vary extremely in type but are all included under the term orchil "lichens." There are several orchil acids: erythrin ($C_{20}H_{22}O_{10}$) from species of *Roccella*, lecanoric acid (orseillic acid ($C_{16}H_{14}O_7$)) from *Lecanora tartarea*, gyrophoric acid ($C_{16}H_{14}O_7$) from *Umbilicaria pustulata* and evernic and ramalic acids (each $C_{17}H_{16}O_7$), from *Evernia prunastri* and *Ramalina pollinaria*. By means of ammonia fermentation—a bacterial process—the natural acids are split into orcin and carbonic acid. Orcin in the presence of air becomes orceine, which is the principal ingredient of orchil. Zopf, in the work referred to, has divided lichen acids into two great organic series: (1) the Fat Series, (2) the Benzole or Aromatic Series. The latter is again divided into subseries: (1) Orcin-derivatives, and (2) Anthracene-derivatives. It is from orcin-derivatives that the blue dye-stuffs are obtained. Parietin belongs to the anthracene group. Zopf and others hold that the alga in its metabolism forms an alcohol, the fungal hypha provides the acid: from these two substances there is formed, as in lecanoric acid, an erythritester or erythrin. The lichen acids occur as an excretion and always on the outside of the hyphae. Though not always easy to see under the microscope, yet in some species, as in *Coniocybe furfuracea*, they form crystals in the lichen up to 20 μ in length. Barbatin, also a colourless acid contained in *Usnea* spp., is also recognisable under high magnification, while several of the naturally coloured acids, such as parietin, are quite distinct. The names given to the different acids generally reflect either the generic or specific name of the lichen from which they were first obtained. Thus salazinic acid, now found in many of our common lichens, was first extracted from *Stereocaulon salazinum*, a rare African species.

Roccella tinctoria is the orchil species most used in southern countries; it was and is now obtained on the rocks bordering the Mediterranean; the best material is got from the Canary Isles, but it is collected from all the African coasts as well as from India and S. America. *Roccella tinctoria* is not a British lichen. Two species, *R. phycopsis* and *R. fucoides* grow sparingly on the rocky cliffs of S.W. England and they also yield erythrin but in less abundance.

Cudbear and litmus are chiefly manufactured from the crustaceous lichen *Lecanora tartarea* which yields lecanoric acid. It is one of the most wide-spread lichens and of fairly rapid growth, so that it soon covers large spaces of tree trunk, rock or soil with its light grey crust. It is a northern plant and is abundant in West Scotland and in the Scandinavian countries. From Norway and Sweden it was brought in ship-loads to

Holland for the preparation of litmus. Cudbear, the Scottish name, is a corruption of Cuthbert, Dr Cuthbert Gordon having started an industry in Glasgow to make use of the West Highland product. Lindsay, writing in 1868, said that orchil was unknown in Stornoway, but cudbear was kept on sale by every grocer and was used by the villagers to dye blankets, shawls, etc.

In Fair Isle, one of the Shetland group, Lindsay found that the colours used in dyeing, many of them from lichens, were bright and gaudy and that the patterns were peculiar to the island. Tradition points to the sailors from the wrecks of the Spanish Armada as the source of the teaching of these patterns, and it has been noted that the same type of colouring and of pattern is characteristic of the long stockings worn by the Spanish peasantry.

In the preparation of litmus or cudbear the orchil lichens are powdered and soaked in ammoniacal liquor for ten or twelve days; alum, potash and lime are added and the mixture is allowed to stand till the maximum degree of colour is observed. During this process—which is a bacterial fermentation—the mass should be constantly stirred to allow contact with the air. Other methods of making cudbear slightly varying in detail from the above are also recommended by different writers.

Litmus paper, which is tinted violet, is prepared by steeping specially manufactured paper in an aqueous solution of litmus. The name litmus or lakmoes is of Dutch origin from *lac*, a resinous dye substance, and *moes*, pulp.

Orchil colours are the most striking, but other beautiful and serviceable dyes have been prepared from a varied series of lichens. From yellow lichens, such as *Letharia vulpina*, a yellow colour is obtained and has been used to dye church candles. *Xanthoria parietina* with alum yields a yellow dye.

Yellow-brown is the colour given by salazinic acid (one of the fat series): it is the acid constituent of *Parmelia conspersa* and of many of our native lichens—though in most of them in too small quantities to be of much service.

Reddish-brown is obtained directly from the very common tree or rock lichen, *Parmelia saxatilis*; it is only necessary to fill a pot with alternate layers of lichen and the material to be dyed, cover with water and boil for some hours: the result is a beautiful and durable red-brown colour. *Lobaria pulmonaria*, *Usnea* sp. and other lichens also give various shades of brown according to treatment. A great deal depends on the quantity of lichens used, the time given to the ammonia fermentation and to the mordants employed. *Lecanora tartarea*, for instance, a true orchil lichen, in a successful experiment gave a delicate brown colour with a pinkish tinge after it had been fermented

in ammonia for ten days and then boiled with alum. It is possible to vary the tints also by an admixture of several kinds of lichen in the dye-pot and by boiling for longer or shorter periods.

As already stated dyeing with lichens was an ancient art, widely known and practised. In all works that touch on lichens from the herbals onward, there are constant notes referring to the dyeing properties of the plants described: thus Lightfoot (1777), in a casual note, comments on the use of *Parmelia omphalodes* from which the natives of the West Highlands obtained a brown dye. On the Continent the more important works directly dealing with dye-lichens are those of Hoffmann (1787) and Westring (1792) who published treatises on the subject illustrated by coloured rectangular blocks of the colours obtained. Slightly later, Westring (1805–9), a Swede, was wishful that his countrymen, in the absence of *Roccella*, should utilise the lichens they had in abundance to obtain the orchil colours: *Lecanora tartarea*, *Umbilicaria pustulata* and species of *Gyrophora* all grow freely in northern countries and all give the desired blue colour.

W. Lauder Lindsay was the first in our country to give serious attention to lichen dyes. He was a doctor in Perth who devoted much time to botanical studies, especially to the study of lichens. In 1854* and 1855 he published an account of his *Experiments on the Dycing Properties of Lichens*, and in 1856 *A Popular History of British Lichens*, with numerous coloured plates which proved for many of us a fascinating introduction to the study of lichens. Though interested in the group chiefly from a scientific point of view, he realised the importance of an organised collection of lichens both to the dyeing industry and to the poor inhabitants of the somewhat desolate regions of the West Highlands. In order to further the use of lichens he published practical instructions as to the kinds of lichen most suitable for purposes of dyeing:

1. That crustaceous dwarf pale-coloured species growing on rocks, and especially on sea-coasts are most likely to yield red and purple for the preparation of orchil, cudbear or litmus.

2. That the colour of the thallus is no indication of colorific power in orchil lichens, inasmuch as the colour substances are the results of chemical action (ammonia fermentation).

3. That alterations in physical characters, chemical composition and consequently in dyeing properties are very liable to be produced by modification in the following external circumstances: (1) degree of moisture; (2) degree of heat; (3) degree of exposure to light and air; (4) climate; (5) elevation above the

* Edin. New Phil. Journ. LVII, pp. 228–249 and LVIII, pp. 56–80 (1855).

sea; (6) habitat (nature of basis or support); (7) age; (8) seasons and atmospheric vicissitudes.

August has been recommended as the best month for collecting; *i.e.* just after the season of greatest light and heat when the accumulation of acids will be at its maximum.

Considerable use has been made of the presence of acids in lichens as a method of determining species. The nature of the acid as evidenced by its colour reaction to alkalies or to calcium hypochlorite, and its occurrence either in the surface tissues or in the medulla have been brought into service by field workers. Nylander was the first to realise the value of the colour tests to systematists, and published a paper on the subject in 1866. It is only necessary in certain doubtful cases of determination to apply a drop of alkaline or calcium hypochlorite solution to secure decisive confirmation. The most efficient method is to place a minute portion of the plant in a water solution under the microscope; a drop of the reagent is introduced and the result however faint or elusive can be easily seen. Generally, however, it is sufficient to touch the plant with a rod dipped in the reagent. A number of species have, somewhat unfortunately, been based on the presence or absence of certain acids in the tissues, though, as a rule, morphological characters are present also.

STUDIES IN ENTOMOGENOUS FUNGI.

(With Plate I and 1 Text-fig.)

IX. AEGERITA.

By T. Petch, B.A., B.Sc.

In 1896, H. J. Webber, while investigating the sooty mould of the orange in Florida, found that the larvae and pupae of the mealy wing (*Aleyrodes citri*) were attacked by a brown fungus, as well as by *Aschersonia*. The fungus formed a seal-brown pustule over the insect and ultimately entirely concealed it, but the pustule could be easily detached from the leaf and the insect was then discovered beneath it. No fructification was observed, and the fungus became known as the "brown mealy-wing fungus."

According to Webber, the hyphae of the fungus develop in the body of the insect, burst out round the margin of the scale, and gradually grow up over it. In an early stage, the fungus forms a compact brown layer round the edge of the insect, but as it develops it covers the scale completely in a dense, hard, smooth stroma. The size of the stroma varies according to the size of the insect attacked, attaining a diameter of 2 mm. and

a thickness of 175–200μ (Plate I*B*). The colour of the stroma is commonly seal-brown, with a shade of chestnut, becoming slightly darker with age, the individual hyphae being light-brown, very tortuous, and only slightly branched.

Webber stated that a hypothallus extended from the base of the stroma over the leaf, forming a compact membrane near the stroma, but becoming dispersed into separate filaments outwards. He traced these filaments for a distance of 13 mm. from the stroma. The hyphae of the hypothallus were colourless, sparingly branched, usually continuous, with only an occasional septum, and 5–7μ diameter. In places where they were somewhat massed together, they become pale brown, similar in colour to the individual hyphae of the stroma. In his summary, Webber described the hypothallus as a silvery white mycelium.

Parkin, in his *Fungi parasitic on Scale Insects*, referred to three collections gathered in Ceylon on *Aleyrodes*, which appeared to resemble Webber's brown mealy-wing fungus. One of these was on *Memecylon capitellatum*, in association with *Aschersonia placenta*; another on *Jasminum Sambac*; and a third on *Calophyllum Walkeri*. Parkin described the pustules of the second collection as rich brown, with a white membranous border from which hyphae radiated out to some extent over the leaf. He also described another gathering, on *Flemingia strobilifera*, in which the leaves bore normal *Aschersonia* stromata, old arrested *Aschersonia* stromata, and others which resembled Webber's fungus; and suggested the possibility that Webber's fungus was a sterile resting form of the *Aschersonia*, though he noted that Webber's account of the development and spread of the brown fungus did not favour such a view.

In 1908, Fawcett summarised Webber's and Parkin's accounts, and stated that in Florida there was no evidence of any connection between the sterile brown fungus and the Aschersonias parasitic on *Aleyrodes citri*. Cultures of the latter had never shown any tendency to develop the brown sterile form of the brown fungus. Attempts to obtain cultures of the brown fungus had been unsuccessful. The only growth under artificial conditions had occurred in one case in which stromata of the brown fungus were placed close to a drop of agar in a hanging drop culture, with the result that short tortuous hyphae grew out from the edge of the stroma. In a supplementary note, Fawcett stated that what appeared to be the spores of the brown fungus had been discovered.

The latter announcement was amplified by Fawcett two years later, principally in two accounts from which the following particulars are taken.

From the margin of the chocolate-brown stroma, colourless

thick-walled hyphae extend over the leaf. Later, usually in the summer or autumn, these hyphae grow out, long and colourless, extending not only over the under surface, where the stromata are situated, but over the margin and along the upper surface. The hyphae on the upper surface bear short lateral branches, on which sporodochia, 60–90μ diameter, are borne. These sporodochia (Plate I *A* , fig. 1) are aggregations of conidia-like, inflated, spherical cells, 12–18μ in diameter. From near the place of attachment of the sporodochium there radiate three to five hypha-like appendages, 150–200μ long, 6–8μ diameter, with one to three septa.

According to Fawcett, the entire aggregation of spherical cells and appendages usually remains united and functions as a spore. In hanging drop cultures of water or 5 per cent. glucose, they produced hyphae identical with those which compose the brown stromata. The first hyphae grew from the ends of the appendages. Experiments demonstrated that the larvae of the white fly could be infected by means of these sporodochia, and the brown stromata produced.

When the sporodochia are abundant, the upper surface of the leaf appears as if powdered with a reddish-brown dust. Fawcett states that this condition was first noticed in 1905. It may be noted that they are present on the specimen of the brown fungus sent by Webber to Parkin, which was collected at Manatee, Florida, March 1896. Perhaps the reason why they were ignored prior to 1908 is simply that no one expected that the stromata would have such a fructification, or that it would occur at such a distance from them.

Fawcett named the fungus, *Aegerita Webberi.* It would appear doubtful whether it is to be regarded as a true conidial fructification, as the apparent conidia do not become free. Fawcett suggested a relationship to the "*Hypochnaceae*" on account of the form of the hyphae, but the latter have no marked characters. The fungus has no resemblance to any stage or part of a *Meliola*, or Sooty Mould.

Numerous specimens of brown sterile stromata have been collected in Ceylon, and I have others from New Zealand, as well as specimens from Florida. On the characters of the stromata, it appeared probable that the forms from these three countries were different species; but the sporodochia in each are identical and they must all be referred to *Aegerita Webberi*, on the available evidence.

Form from Florida.

Of this I have specimens which were sent by Webber to Parkin, and others kindly forwarded to me by Professor H. S. Fawcett. Both collections are on *Aleyrodes citri* on orange.

The stromata are rufous brown to rather light purple-brown, often mottled, glabrous, or minutely pruinose at first, flattened pulvinate or almost plane, more or less oval, up to 2 mm. long and 1·5 mm. wide, with a narrow, brown, fibrillose margin. They are frequently depressed in the centre, and often ring-shaped, not completely concealing the insect.

The hyphae which radiate from the stroma over the surface of the leaf are pale brown, 4–8μ diameter, moderately thick-walled, somewhat flexuose, interlacing and sometimes fusing laterally in strands of three or four, but not forming a continuous film except at the edge of the stroma. These coarse hyphae run practically singly over the leaf and are not visible until the leaf is examined under a one inch objective.

Sporodochia occur along the hyphae on the lower surface of the leaf, but chiefly on the upper surface, where they may be massed in dense patches. Under such patches the hyphae are coalescent in a rather close network, the upper hyphae of which are brown, thin-walled, septate, up to 12μ diameter, and more or less straight, while the lower are flexuose, hyaline, and united into a continuous film.

The scale persists beneath the stroma and is readily separable from it, the stroma being a thin layer, convex above, but concave below, following the shape of the scale. It is evidently hyphal, or plectenchymatous, except in the external layer, where the hyphae are fused together and appear in section as a parenchymatous cortical layer, one cell deep. The hyphae of the stroma are 3–8μ diameter, pale brown, intertwined, and thin-walled. The stroma is not sclerotioid, nor can it be styled hard. In section it appears yellow-brown.

Form from Ceylon.

The Ceylon specimens, in those collections in which the host insect can be ascertained, occur, as a rule, on *Aleyrodes*, but sometimes on *Aspidiotus*. In very many cases, however, the host insect cannot be determined, as all the insects on the leaves have been attacked and no remains of them persist in the stromata. Parkin noted, in the case of his specimen on *Calophyllum*, that the brown pustules were not proved to be on scale insects. Proof, by discovery of the insect, is impossible in most cases, as the insect has been completely destroyed by the fungus. It is only rarely, and in young stromata, that

remains of the scale are to be found beneath the stroma. In this respect, the Ceylon fungus differs remarkably from the Florida form, but the difference may be due in part to differences in the species of insects attacked. It is possible that the scales of *Aleyrodes citri* and *A. nubifera* may be more resistant to the action of the fungus than those of the Ceylon insects.

The full-grown stromata are purple-brown, glabrous, smooth, convex or scutate, up to 2 mm. diameter, with a narrow, white or pale brown, fibrillose margin. Old specimens may have a recurved margin. In some cases, coarse hyphae, hyaline or very pale brown, radiate in strands from the stroma, but not regularly all round. More generally, however, a continuous hyaline film spreads from the stromata over the leaf, sometimes covering the whole of the lower surface. When dry, this film often separates from the leaf in large patches.

The hyphae which radiate from the stroma, in the first case, are 2–6μ diameter, regular, rarely flexuose, fusing laterally. Many of these hyphae are solid; others are thick-walled, septate, and have granular contents. As a rule, they form a layer only one hypha thick. The edges of these hyphae often appear ragged, owing to the development of a marginal film.

The hyaline film consists of a close network of stout hyphae running in all directions, the interspaces being filled by an amorphous membrane. The main hyphae are identical with those already described, but the branches between them are more flexuose and intertwined, and tend to lose their outline and become merged in the hyaline membrane.

Sporodochia are not common on the Ceylon specimens. They occur scattered over the film on the lower surface of the leaf.

The stromata are up to 0·5 mm. thick in the centre. In section, viewed macroscopically, they show a dense, dark purple-brown, peripheral zone, followed by a brownish white tissue which becomes looser towards the base. By transmitted light, the peripheral zone appears pale brown, with a narrow, dark brown, limiting zone internally, while the remainder of the stroma appears hyaline. The peripheral zone occupies about one half the thickness of the stroma, and is parenchymatous, displaying in section polygonal or rounded "cells," up to 8μ diameter, or elongated "cells," parallel to the periphery, about 16 × 6μ. The lower hyaline half of the stroma consists of loosely intertwined hyphae with large numbers of irregular masses of calcium oxalate. The hyphae of the stroma are up to 10μ diameter, thin-walled, pale brown to almost hyaline, and irregularly contorted. The stromata are not sclerotioid.

In a specimen on *Aleyrodes* on *Jasminum Sambac*, the stromata are young, pale purple-brown, and do not differ

greatly in appearance from the Florida form. But they do not contain any remains of the insect. In a collection of similar young specimens on *Turpinia*, the insect is present beneath the stromata.

In another specimen, on an *Aleyrodes* on *Sarcococca pruniformis*, Hakgala, May 1910, the stromata are moderately thick, but the tissue is composed merely of loose hyphae which do not form a pseudoparenchyma, and the stromata are densely filled throughout with irregular masses of calcium oxalate.

A gathering on *Aspidiotus* on *Psychotria Thwaitesii*, Hakgala, May 1910, contains several abnormal forms. Some stromata are normal; others have a loose, strigose mass of pale brown hyphae at one side; while others consist entirely of a loose, pulvinate, strigose mass of hyphae. These hyphae are pale yellow-brown, thin-walled, septate, like the stouter hyphae in the normal narrow border of the stroma. The same abnormalities occur in specimens on *Allophylus zeylanicus*, Hakgala, May 1912, and on *Pavetta indica*, Hakgala, May 1912.

The Ceylon form differs from the Florida form in its thicker stromata, the parenchymatous inner tissue, and the membranous film extending over the leaf. As regards the latter, the Florida form is probably variable, since Webber referred to the hypothallus as a silvery white mycelium; and the parenchymatous tissue is merely an extension of the single parenchymatous outer layer of the Florida form. All the differences may be ascribed to a more advanced development of the fungus under Ceylon conditions.

Form from New Zealand.

Specimens from New Zealand, on an undetermined scale on *Melicytus ramiflorus* Forst., have been kindly forwarded by Mr G. H. Cunningham, who informs me that the fungus appears to be common in the forests of that country. It was collected in New Zealand by Colenso, and there are specimens in Herb. Kew, labelled "*Aschersonia*. New Zd., Colenso 3804 *a*. *Aschersonia zeylanica* Berk." in Berkeley's handwriting. The name was not published.

The stromata are dark purple-brown, convex, rugose, up to 2 mm. diameter, surrounded by a brown, strigose layer of coarse hyphae radiating from the stromata over the leaf and forming a byssoid film which becomes paler outwards.

The film is composed of two layers. The lower layer consists of hyaline hyphae, 4–6μ diameter, usually thick-walled, much curved and interlaced and forming a continuous sheet. Over this runs a network of pale brown, thick-walled, septate, regular hyphae, up to 8μ diameter.

Sporodochia occur in dense clusters along the margin of the leaf on the lower surface (on which the stromata are situated) and may extend over to the upper surface.

The stromata are up to 0·5 mm. thick. The base is flat, as in the Ceylon form, and no trace of the insect persists beneath it. In section, viewed macroscopically, the stroma shows a dense, dark purple, subtranslucent, peripheral zone about 125μ thick, followed by a pale brownish region which becomes looser and whiter in the centre of the base. By transmitted light, the superficial layer is brown, but the remainder of the peripheral zone is hyaline; this is followed by a yellow-brown region, hyaline at the base. Except for a small region in the centre of the base the whole of the stroma is parenchymatous, with small cells, 6–8μ diameter, or oval or elongated cells, up to 20 × 10μ. The cells in the peripheral zone are usually small and polygonal, the larger cells occurring in the lower half of the stroma, with their long axes parallel to the periphery, the hyphal nature of the stroma being thus more clearly indicated in that region. The cells have strongly refractive contents, and on that account the structure of the stroma is somewhat obscure when the section is examined in water, but the limits of the cells become clear when the section is mounted in chloroform or xylol.

The hyphae of the stroma are irregular, 4–8μ diameter, sometimes expanding to 12μ, thin-walled, septate. A few thick-walled hyphae, 2μ diameter, occur towards the periphery. In a small region in the centre of the base the hyphae are loosely intertwined and mingled with crystals of calcium oxalate. All the hyphae have solid contents in discontinuous, ovoid or irregular masses, free from the wall of the hypha. These bodies do not dissolve in alcohol, and are unaffected by chloroform or xylol.

The stromata in the Colenso specimen in Herb. Kew are similar to the above in external appearance, and show the dark peripheral zone in section. But the specimen examined was hollow in the centre, and contained an abundance of masses of calcium oxalate. The solid cell contents occurred only sparingly here and there, most of the cells lacking them.

The New Zealand form differs from the Ceylon form in the more parenchymatous stroma and the stouter film extending over the leaf. Here again the differences appear to be due merely to a stronger development of the fungus.

Comparison of the stromata.

In the specimens from Florida, the stromata are parenchymatous only in a single external layer; in the Ceylon form, they are parenchymatous for half their thickness; while in the New Zealand form they are parenchymatous down to the base. In

all cases the hyphae of the stromata are thin-walled, and the stromata are not sclerotioid or hard. In the New Zealand form, ovoid or irregular masses occur within the hyphae of the stroma.

In the Florida form, stout hyphae spread separately from the stromata over the leaf, uniting into a continuous film where the sporodochia are produced; in the Ceylon form, the spreading hyphae unite from the first into a hyaline film surrounding the stromata and covering the under surface of the leaf; in the New Zealand form a stouter byssoid film is produced, consisting of a hyaline continuous layer overlaid by a network of stout, pale brown hyphae.

In the Florida form, the scale persists beneath the stroma, but in both the Ceylon and the New Zealand forms no trace of the insect remains under the fully developed stroma.

The sporodochia.

In the Florida form, the sporodochia occur chiefly in dense groups on the upper surface of the leaf, but they may also occur on the lower surface in similar groups near the margin or scattered along the repent hyphae. In the Ceylon collections, sporodochia are not numerous, and they occur on the lower surface scattered over the hyaline film. In the New Zealand form, the sporodochia occur chiefly clustered along the margin on the lower surface of the leaf, but they may extend over to the upper surface. In all cases the stromata are on the lower surface of the leaf.

The colour of the sporodochia varies slightly between the different forms. Those in the New Zealand specimens are dark rufous brown. In the Ceylon examples they are pale cinnamon brown, and in the Florida specimens rufous brown.

The sporodochium, about 0·1 mm. diameter, is a globose aggregate of spherical or ellipsoid cells, from which radiate three to six, usually four, appendages or setae (Plate I *A*, fig. 1). The conidia-like cells are thin-walled, hyaline or pale brown, smooth, either 12–16μ diameter, or 13–20 × 10–16μ. They are in short, branching, curved chains (Plate I *A*, fig. 6), and do not separate from each other or from the sporodochium. The setae are pale brown or almost hyaline, cylindrical, two to three septate, equal or slightly attenuated upwards, with an obtuse apex 50–180μ long, 6–9μ diameter, usually thin-walled, but sometimes with a wall 1μ thick (Plate I *A*, fig. 3). In some setae the basal cell is slightly inflated, and others may be slightly constricted at the septa, but in general they are uniformly cylindrical. The apex of the immature seta is often acuminate, and in one instance a spear-shaped tip was observed (Plate I *A*, fig. 5).

The sporodochia arise from the repent hyphae singly, on short, lax, flexuose, septate stalks, 4–5 μ diameter. At the apex, the stalk expands into a pyriform head, about 30 μ high, and 12 μ diameter above, which gives rise to chains of oval or globose cells, or to setae, at any point (Plate I *A*, fig. 2). The chains of cells are usually irregularly curved, and branch repeatedly, the branches spreading, or curving parallel to the original chain, or even curving backwards. The chains are consequently variously intertwined, and do not separate when the sporodochium is submitted to pressure under a cover glass. If, however, the cover glass is moved from side to side, especially after treatment of the sporodochium with lactic acid, the apex of the stalk and the initial cells break up, and the sporodochium is resolved into short, curved chains of cells.

The setae frequently arise in pairs (Plate I *A*, fig. 4). They may originate from a common basal cell attached to the apex of the stalk, or as lateral branches in a chain of cells. They originate in the sporodochium, not beneath it.

Cultures.

Fawcett, in 1908, stated in the body of his paper, that attempts to obtain cultures of the brown fungus had been unsuccessful; but in an appendix he recorded that what appeared to be the spores of the fungus (*i.e.* the sporodochia) had been discovered, and these were germinating in hanging drop cultures of sugar solutions.

In his paper of 1910, Fawcett wrote that "These *Aegerita* sporodochia, when germinated in hanging drop cultures of sterile water and in 5 per cent. glucose solution, were seen to produce hyphae identical with those which compose the brown stromata on the white fly larvae. When germinating, the first hyphae grow out either from the sporodochia or from the ends of the appendages. These branch rather sparingly, but in a few days, in 5 per cent. glucose solution, form a network by the intercrossing of the branches."

Specimens were collected at Hakgala on an *Aleyrodes* on *Turpinia pomifera* in September 1923. The stromata were young, having evidently been formed during recent wet weather after the dry season which prevails during the first half of the year on that side of the hills. The scale insects still persisted beneath the stromata, and hyphae were beginning to radiate from the stromata over the leaf. Only on one leaf was it possible to find sporodochia, and these, though full size, were still white.

Sporodochia were picked off the leaf with a sterile needle, and placed in hanging drops of Raulin-maize meal agar in damp cells. Growth of hyphae was observed after two days, but in no

instance did it proceed from the cells of the sporodochium. In one instance, the mycelium arose from a *Cladosporium* spore, and in another, from a *Pestalozzia* spore, entangled among the cells of the sporodochium. The sporodochia in the hanging drops were treated with lactic acid, and then broken up into their component chains of cells; in no case could it be seen that any growth had occurred from the globose cells or from the setae. A yeast developed round the sporodochium in one hanging drop.

Sporodochia were also placed on slants of maize-meal agar, maize-meal agar plus Raulin's fluid, and neutral Raulin agar, but in all cases the tubes produced either a *Penicillium*, or a *Pestalozzia*, or both.

Others were sown, singly, in flasks of neutral Raulin's fluid, and Naegeli's solution, No. 3, with cane sugar, three of each series. In each series no growth occurred in one flask, while another in each series developed *Penicillium* and *Pestalozzia* respectively. The third flask in the neutral Raulin series developed a dense, submerged, dark green mycelium; this ultimately formed a densely tomentose layer at the surface, with oval conidia, from $4 \times 3\mu$ to $16 \times 5\mu$; and transfers of these conidia to bean agar produced compact, green patches of a *Cladosporium*. In the third flask in the Naegeli series, a red-brown, submerged mass of mycelium was produced, which proved to be an unidentified laboratory contamination.

In January 1924, after the monsoon rains, cultures of sporodochia from the same tree were again attempted. Six flasks of Naegeli's fluid were inoculated with a single sporodochium each. In one of these no development occurred; the others developed *Pestalozzia*, *Cladosporium*, *Fusarium*, and other Hyphomycetes.

Attempts were also made to obtain cultures from the stromata. Horizontal sections of these were cut with a sterile knife, the outer layer being discarded, and the base left adherent to the leaf. These were placed in tubes of maize-meal agar, and neutral Raulin agar, and flasks of Raulin's and Naegeli's fluids. In one flask of Raulin's fluid, no growth occurred, while in all the other cases *Penicillium*, *Cladosporium*, and *Pestalozzia* developed.

In another series, the stromata were brushed over with alcohol, all the hyphae which spread from them over the leaf being either broken by the brush or cut with a sterile knife. They were then detached from the leaf and the outer layer shaved off. One lot was cut into small pieces; another was ground up in a glass mortar with sterile sand. The latter process was not very successful, the stromata being too soft and adhesive to break up into small fragments. Both lots were then plated out separately in neutral Raulin agar. Growths

were obtained of *Penicillium*, *Pestalozzia*, *Botrytis*, and *Cladosporium*, but no growth could be detected from the majority of the fragments of the stromata.

In one instance, however, a development of hyphae was noted from one piece of stroma, and this was transferred to a tube of neutral Raulin agar. Growth was slow, a compact, strongly convoluted stroma, about 2·5 cm. long, 1·5 cm. broad, and 7 mm. high, being produced in four months. The stroma was minutely tomentose, black-brown, with a reddish, or purplish, fuscous, tomentose surface layer. It proved to be hollow, forming an irregular shell, about 1 mm. thick. Its advancing margin was entirely submerged, about 1 mm. broad, and composed of radiating hyphae, but the remainder of the stroma was plectenchymatous, and in its subsequent growth had been raised above the surface of the agar in irregular folds.

The hyphae of the advancing margin were pale purple-brown, fairly regular, septate, 3μ diameter, sometimes with swellings at the septa, with other hyphae, closely septate and composed of moniliform chains of cells, up to 10μ diameter. The stroma was yellow-brown or pale purple-brown in section by transmitted light, and consisted of cells up to 16 × 10μ. In the old culture, the contents of these cells were strongly refractive. The superficial layer consisted of rigid, septate hyphae, up to 30–80μ high, 4μ diameter, and globose cells, about 8μ diameter, in short chains or irregular clusters. The latter cells resembled the segments of the moniliform hyphae found in the advancing margin, while the short, rigid hyphae bore a considerable resemblance to the setae of the *Aegerita* sporodochia. The stroma was evidently built up by the fusion of the two kinds of hyphae.

When pieces of the stroma in the foregoing culture were transferred to slants of Naegeli agar, a similar stroma was produced, but the colour was greenish black. The structure was the same, but the seta-like hyphae were shorter, about 30μ long.

On transfers to maize meal slants, no superficial stroma was formed. The mycelium was greenish black, submerged, with a slight grey superficial layer, and on the surface of this, small fuscous pycnidia, 0·3 mm. diameter, with very minute spores, were produced.

It was unfortunately not possible to continue these investigations further. The stromata obtained in culture were possibly those of *Aegerita Webberi*, though probably not pure. The stromata of *Aegerita* are frequently parasitised by pycnidial fungi, and it may have happened that one of these was present in the cultures, but developed fructifications only on the maize meal. The cells of the stroma resembled those of the *Aegerita*

stroma in their refractive contents, and in their general shape and size, though little weight can be placed on the latter. Further, the short rigid hyphae on the exterior of the stroma resembled the setae of the *Aegerita* sporodochium. That the shape of the stroma differed from that of the *Aegerita* stroma is perhaps immaterial; the latter develops at the expense of a limited supply of food, viz., that contained in a single scale insect, while the former had a food supply available over a large area. On the other hand, the stromata obtained in culture did not produce repent hyphae extending indefinitely from the margin, even when they had come in contact with the sides of the tube.

Some apology is needed for presenting these incomplete results, but it is possible that future workers may find them of some use. The difficulties of obtaining pure cultures of *Aegerita Webberi* are obvious. The cells of the sporodochia do not separate from one another naturally, and consequently attempts must be made to start cultures from entire sporodochia, which may have spores of other fungi entangled in them. Similarly, the stromata in their development may overgrow and include fungus spores, and growth may occur from these when fragments of the stroma are used. Foreign spores may sometimes be seen embedded in the surface layers of the stroma.

It might be suggested that the stromata of *Aegerita Webberi* are not pure growths of a single fungus, but a mixture, the barren stromata being produced by the growth of a superparasite on an entomogenous fungus. It is known that when the stromata of *Aschersonia placenta* are attacked by one species of *Cladosporium*, they become more discoid, greenish yellow and corky, quite different in appearance, colour, and texture from the normal stromata; the pycnidia are not suppressed, but the spores and paraphyses are imperfectly developed and form a brown lining to the pycnidium. Again, in a collection of the same species, parasitised by a *Coniothyrium*, the *Aschersonia* stromata are hard, discoid, and purple-brown, the pycnidia, spores, and paraphyses being in the same condition as in the foregoing. Such specimens, if gathered alone, could not be classified correctly, and might be taken to be new species, as indeed has happened in the case of similarly parasitised entomogenous fungi, though the abnormal condition of the contents of the pycnidia should give cause for hesitation.

It does not, however, seem probable that the *Aegerita* stroma is due to parasitism of this nature. In other entomogenous fungi, it is usual to find normal specimens in company with the parasitised stromata. On the other hand, the stromata of *Aegerita Webberi* occur in large numbers, all of the same

structure and appearance. They do occur with other entomogenous fungi occasionally, but the majority of the collections made in Ceylon consist solely of *Aegerita* stromata, no other stromata being present of which they might be considered parasitised examples.

Nor does it appear probable that the stromata are formed from parasitised sporodochia. In that case, one would expect to find examples in which the insect bore only repent hyphae and sporodochia. I have one specimen in which mycelium bearing sporodochia spreads from a scale insect which does not bear an *Aegerita* stroma; but it is an exceptional case, and the insect is wedged beneath a scale leaf of *Juniperus*, where a normal *Aegerita* stroma could not be formed. The sporodochia of *Aegerita Webberi*, in general, do not occur on the scale insects, but on repent hyphae which extend from the stromata over the leaf.

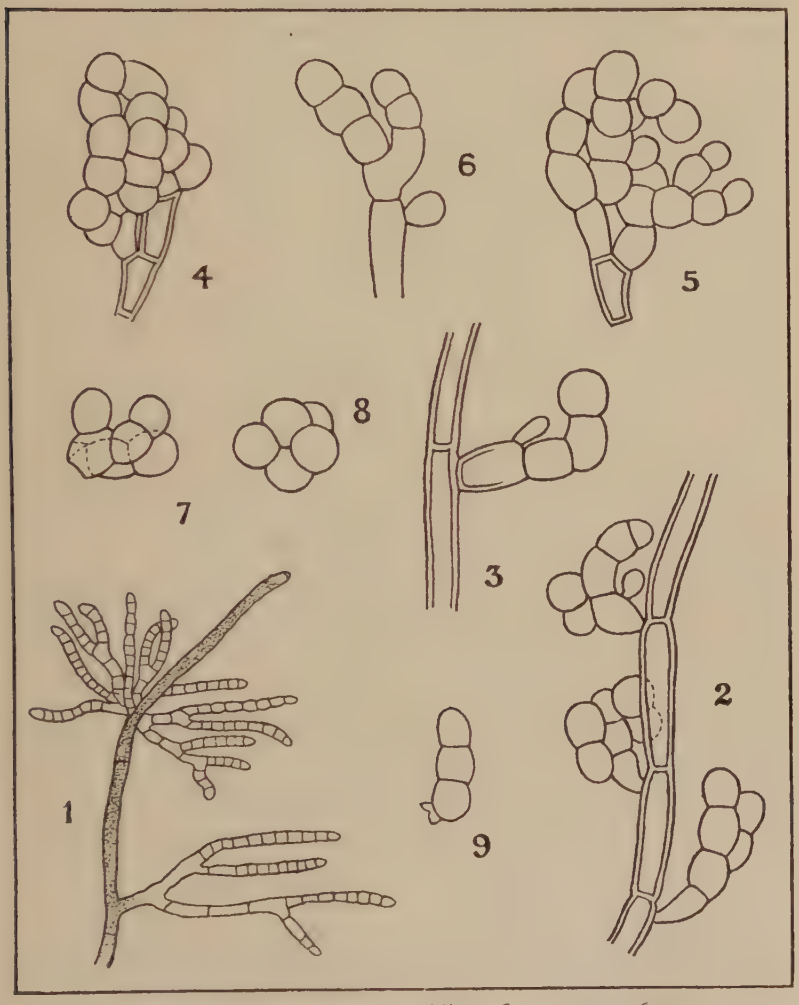
Fawcett's hanging drop cultures do not appear to afford conclusive evidence of the germination of the sporodochia. Similar growths of mycelium were obtained in the present experiments, but it was determined that they did not arise from the cells of the sporodochium. The only conclusive evidence would be the production of sporodochia, or stromata, identical in structure with those of *Aegerita Webberi*.

The failure to obtain pure cultures from the sporodochia or stromata throws considerable doubt on the validity of the accepted method of distributing this fungus for the purpose of destroying *Aleyrodes*. It is claimed that successful propagation is obtained by grinding up in water leaves which bear the fungus, and spraying trees infested with *Aleyrodes* with the mixture. This argues a ready germination of the sporodochia, or a rapid growth from fragments of the stroma, both of which are contrary to the experience of everyone who has tried to cultivate this fungus.

Conidial forms of *Septobasidium*.

In *Bull. Soc. Myc. France*, xl, p. 29 (1924), Patouillard described *Septobasidium lanosum*, parasitic on coccids on *Citrus decumana* (Pumelo) in Tonkin. The fungus forms extensive resupinate patches, dark brown (ombre-brun) with a reddish sheen, woolly, with a narrow grey margin. Its context is soft and floccose, composed of erect, brown, branching hyphae, fasciculate in bundles of six to ten, not interwoven into a superficial sheet. The probasidia are hyaline, globose, scarcely pedicellate, 12–15μ diameter, situated on the upper part of the erect hyphae. Above the point of insertion of the probasidia, the hyphae continue as circinate branches, 4–6μ diameter and of varying length.

Mixed with the hyphae which bear the probasidia, and identical with them in appearance, though not coiled in tendrils at the ends of the branches, are a large number of other hyphae which bear short, hyaline, lateral branches, simple or forked,



Text-fig. 1. Conidial *Septobasidium*; figures 2–9, ×600.

solitary or in tufts, 30–75 μ long, thin-walled, capable of dividing by transverse septa into a large number of segments, 4–5 μ long, which can separate ("susceptibles de se séparer") from one another and so form an abundance of conidia. After the appear-

ance of the septa, the lateral branch is constricted at the septa and appears moniliform, and the segments or conidia are ovoid.

Patouillard did not find probasidia and conidia on the same hypha, though they occur on similar hyphae in the same individual specimen. He records that similar conidia occur in *Septobasidium albidum*, which is also found on coccids on *Citrus*; but in the latter species the conidial specimens are almost always destitute of probasidia.

Part of Patouillard's figure is reproduced herewith (Text-fig. 1). It will be seen that the lateral branches, in general, terminate in a cell which increases in width upwards and bears chains of conidia at the apex.

A similar fungus, on a scale insect on tea from Yaizu, Province Suruga, Formosa, has been forwarded to me by Mr K. Hara.

It forms loosely woolly, dark purple-brown tufts, 0·5 mm. thick, oval, a few millimetres long and broad, which become confluent in large patches. The hyphae are crowded, more or less erect, flexuose and intertwined, reddish brown or dark yellow-brown, paler at the apex, septate, thick-walled, minutely rough, 6–8μ diameter, sparingly branched. The hypha may be attenuated above, with an acute apex, or it may terminate in a group of spore-like bodies.

The spore groups arise from the hypha below a septum, or at the apex, or on short lateral branches, up to 50μ long, which are two to three septate. In the first case a curved basal cell, expanding upwards, arises from the hypha, and bears two or more short chains of cells, usually with three cells in a chain. These chains resemble three-celled, cylindric spores, constricted at the septa and usually curved, about 24 × 10μ. They do not, however, become free, but give rise to similar chains either laterally or apically, forming a loose head, either globose or oval, up to 40 × 25μ. The chains arise as a rule from the apex of the basal cell, but they may originate at any point on it. The short lateral branches terminate in similar clusters, but they may bear in addition chains of cells, each arising below a septum of the branch.

Some of the short chains may occasionally be found detached, but in that case fragments of another cell are attached at the base, showing that the chain has been broken off (Text-fig. 9). As a rule, the spore cluster, including the basal cell, is detached as a whole (Text-figs. 4, 5). The basal cell is usually thick-walled.

The chains are not united into a solid mass, and consequently the spore group does not resemble the conidium of *Septosporium*.

Text-figs. 2 and 3 show the clusters of chains developing laterally on a hypha, and Text-fig. 6 a developing apical cluster.

Text-figs. 4 and 5 show two detached clusters, and Text-fig. 9 a single chain. Text-figs. 7 and 8 give lateral and apical views respectively of a small detached cluster.

Probasidia have not been observed in this specimen, but from its general structure it would appear probable that it is a conidial form of a *Septobasidium*.

The resemblances between the foregoing "conidial" forms and the sporodochia of *Aegerita Webberi* are scarcely sufficiently marked to justify the conclusion that the latter is a form of a *Septobasidium*. Nevertheless, the fact that such forms do occur in *Septobasidium* suggests that possibility, and consequently it has been considered worth while to refer to them here. No links have been found between *Aegerita Webberi* and any Ceylon species of *Septobasidium*. *Septobasidium Thwaitesii* forms thin, flat, glabrous stromata, purple-brown in colour, which are circular or oval, with a byssoid margin, at first, and subsequently coalesce into a continuous sheet. But these stromata are composed of loose hyphae internally, and do not exhibit any trace of the parenchymatous structure of *Aegerita Webberi*.

Fungi parasitic on *Aegerita Webberi*.

Morrill and Back recorded the occurrence of a parasitic fungus on *Aegerita Webberi* in Florida, which was referred to *Coniothyrium*. They stated that it formed a dense, dark greenish, hard growth over the pustule of the brown fungus, and presented a surface roughened by numerous pustular elevations. I have specimens from Fawcett which agree exactly with Morrill and Back's figure, the pustular elevations being pycnidia.

A similar fungus occurs on *Aegerita Webberi* in Ceylon, and has been described by the writer as *Sirosphaera chlorostoma* (*Trans. Brit. Myc. Soc.* viii, p. 208 (1923)). In the original description it was stated that the pycnidia bore scattered erect hairs, up to 44μ high, 6μ diameter below, tapering upwards. A re-examination of the Ceylon examples in comparison with specimens from Florida shows that there are, in addition, slender yellow acicular setae in spreading fascicles: these are apparently detersive and were overlooked at the previous examination.

A Florida specimen of *Aegerita Webberi* from Professor H. S. Fawcett bears good examples of this *Sirosphaera*. The pycnidia are conoid, about 0·2 mm. diameter, clustered, often in a ring round the edge of the *Aegerita* stroma. The conidia are brown in mass, pale fuscous individually, narrow-oval or oblong-oval, 2–4 × 1·5–2μ, or subglobose, 1·5–2·5μ diameter. The pycnidia bear short scattered hairs, but they differ from the Ceylon form in the copious development of the acicular setae. These latter

occur in spreading fascicles, not only on the pycnidia, but also on the exposed parts of the stroma, in such abundance that the whole fungus appears green. The individual setae are yellow, rigid, up to 50μ long, 1·5μ diameter at the base, attenuated upwards regularly to the acute apex.

The Florida form does not differ from the Ceylon form except in the more abundant development of the setae, and it is doubtless the same species.

A specimen of *Aegerita Webberi*, collected on *Psychotria* at Hakgala, March 1922, has the stroma blackened by minute, pulvinate, close-set or confluent sporodochia. These sporodochia are parenchymatous at the base, and the conidiophores, after a short base, 8μ high and 2μ diameter, are branched, with branches about 6μ long. These branches bear at their apices densely clustered, flask-shaped phialides, 8μ long. The conidia are hyaline, oval, continuous, 2 × 1μ. This species appears to be a *Tubercularia*, which may be known as *Tubercularia epimyces*. From the stroma, hyphae radiate in a film over the leaf; these are fuscous, 2μ diameter, septate, thin-walled, slightly irregular, and united laterally into strands. On these hyphae are blackish-fuscous parenchymatous bodies, about 50μ diameter, which may be developing pycnidia; they bear irregularly conical fascicles of hyphae, or single, erect hyphae, up to 30μ high. The same fungus has also been found on stromata of *Torrubiella*.

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EXPLANATION OF PLATE.

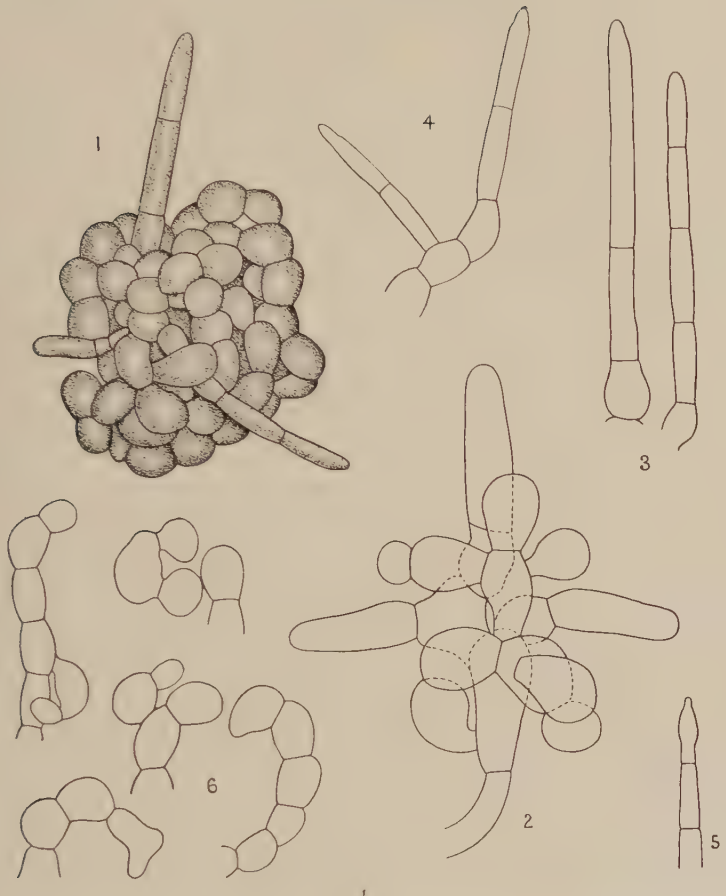
Plate I.

A.

Fig. 1. A sporodochium. × 400.
Fig. 2. Early stage of formation of a sporodochium. × 750.
Fig. 3. Setae. × 400.
Fig. 4. Two setae arising from the same chain of cells. × 400.
Fig. 5. Seta with an acuminate tip. × 400.
Fig. 6. Chains of cells from a sporodochium. × 400.

B.

Aegerita Webberi, specimen from New Zealand. Natural size.



A

B

Aegerita Webberi

MATULA.

By T. Petch, B.A., B.Sc.

(With Plates II and III, and 2 Text-figs.)

In *Fungi Cubenses*, Berkeley instituted a new genus, *Michenera* B. and C., with the characters, "Placentaeformis, disco ceraceo; sporis magnis limoniformibus longe pedicellatis." The type species, *Michenera artocreas* B. and C., was said to occur on dead trunks of trees in Cuba (Wright 262), and on Black Oak in the United States (Curtis 5609). It was from one-quarter to three-quarters of an inch across; margin raised, white tomentose; hymenium cracked, umber, resembling that of *Corticium ochroleucum*; spores, including the stem, ·0025 inch long, without the stem ·001. In the Introduction to the paper, Berkeley stated that "Michenera, with which we have long been acquainted as occurring in the United States, is peculiarly interesting in point of structure."

Later, in *The Fungi of Ceylon*, Berkeley and Broome described the genus *Artocreas*, "Receptaculum commune distinctum; hymenium planum e sporis magnis pulveraceum." The type species, *Artocreas poroniaeforme* B. and Br., Thwaites 309, was "erumpens; receptaculo hemisphaerico, pallide rufo; hymenio albido; sporis globosis. Looking just like an imperfect *Crucibulum*. Spores globose, ·0009 in diameter."

To the description of the Ceylon species, Berkeley and Broome added: "A species of the same very distinct genus occurs in the United States"; and they proceeded to describe the latter as "*Artocreas Micheneri* B. and C. Extus album tomentosum; hymenio rufo; sporis ovatis apiculatis pedicellatis (Nos. 3529, 3773). Pennsylvania, Michener. About $\frac{1}{4}$ of an inch wide, or more by confluence; spores ovate, with a long obtuse apiculus, ·001$\frac{3}{4}$ long without the apiculus."

It would appear that Berkeley had forgotten that he had already described this second species as *Michenera artocreas*. Against that supposition, it has been pointed out that Berkeley did not cite the same collection numbers for *Artocreas Micheneri* as for *Michenera artocreas*. But all doubt as to Berkeley's intention is removed by his note in the supplement to *The Fungi of Ceylon*, where it is stated (p. 83), "*Artocreas* B. and Br. It is necessary to remark that this is synonymous with *Michenera* B. and Curtis, and that *Artrocreas* B. and C. (*sic*) is the same with *Michenera artocreas* B. and C., Cuban Fungi, No. 413." Thus Berkeley withdrew the genus *Artocreas*.

In 1888, Massee published an account of the Ceylon fungus *Artocreas poroniaeforme*, and instituted for it a new genus

Matula, which he placed in a new order of Gasteromycetes, Matuleae, intermediate between the Nidulariaceae and the Hymenogastraceae. According to Massee, the leading features of the plant were: "(1) a peridium closed above by an epiphragm until all differentiation is completed; (2) a gleba broken up into numerous cavities or loculi by dissepiments bearing basidia on their free surfaces." The basidia were described as "very primitive in structure, being slightly or not at all thickened at the apex, and producing usually a single spore which at first appears as an obovate terminal cell attached by a broad base. While the spores are still young and obovate they are set free by the total disappearance of the basidia, afterwards becoming spherical and increasing considerably in size."

The type species of the genus *Michenera* is *Michenera artocreas* B. and C. The type species of the genus *Artocreas* is *Artocreas poroniaeforme* B. and Br. Berkeley withdrew the latter genus, as being synonymous with *Michenera*. The Ceylon fungus consequently became *Michenera poroniaeformis*, though Berkeley did not publish that combination. When Massee decided that the Ceylon fungus was not co-generic with *Michenera artocreas*, he did not revive Berkeley's generic name *Artocreas*, but founded a new genus *Matula*.

It appears to have been generally assumed that the type of *Michenera artocreas* B. and C. is the United States specimen, Curtis 5609, and enquiries into the identity of *Michenera* have generally been based on the North American species. But the type, by Berkeley's citation, is Wright 262, of the second Wright collection, and the type locality is Cuba, not the United States.

In the modern school of nomenclature, type specimens and type localities are assigned the principal part in the determination of an author's idea of his species. Hence it is of the greatest importance that these should be quoted correctly. It has been a fairly common practice to claim North American localities as type localities of Cuban fungi, owing to the method adopted by Berkeley in the publication of *Fungi Cubenses*. He did not consider it necessary to give the locality, Cuba, but, after some of the species enumerated, he added, under habitat, a list of localities which are not Cuban. That is explained in the introduction, where Berkeley wrote: "The habitats appended to species already described are taken from specimens in our herbaria, or such as have passed through our hands." The paper shows that the restriction to species already described was not observed, for Berkeley added extra-Cuban habitats to some of his new species. It is most probable that, as in the case of *Michenera*, he had had these new species in his herbarium for some time, although he had not published descriptions.

It is also clear, from an examination of the specimens, that

in many cases the Cuban fungus is not the same as the North American one. Indeed, it would appear that many of these extra-Cuban localities were added from memory, or from macroscopic examination only. In such cases, where new species are concerned, the Cuban fungus should, by Berkeley's citation, be the type.

For example, *Xylaria clavulata* B. and C. was recorded without descriptions from Wright 312, with the synonym *Sphaeria clavulata* Schw., and the extra-Cuban localities, United States and Venezuela. But Wright 312 is an immature *Xylaria*, while *Sphaeria clavulata* Schw. is a *Cordyceps*. The two fungi are not related, but as *Sphaeria clavulata* antedates *Xylaria clavulata*, no difficulty arises.

Again, *Nectria diploa* B. and C. was described as a new species from Wright 606, and the extra-Cuban habitat, Carolina Inf., was added, with the number Car. Inf., 4029. The latter is not the same as the Cuban species, and the description does not fit it. The type specimen is Wright 606, the type locality Cuba, and the original description was evidently drawn up from the Cuban fungus. This example demonstrates that it is not correct to suppose that, because Berkeley had, or thought he had, a previous specimen from another locality, the latter is the type.

Consequently, in clearing up the problem of *Michenera* it is necessary to determine whether the North American fungus is identical with the Cuban species, and whether either is co-generic with the Ceylon species.

The Cuban specimen, Wright 262 in Herb. Paris, was examined by Patouillard, who published a description of it in 1891, and again in 1900. Except in a few minor details, Patouillard's description agrees with Lyman's account of the North American fungus quoted below. As, however, the specimen in Herb. Paris is only a co-type, there was still a possibility that North American and Cuban specimens might have been confused in the distribution. To decide the point, Miss Wakefield has kindly examined the type in Herb. Kew, and finds that Wright 262 has the same structure as Curtis 5609. Hence the North American and the Cuban specimens are at least co-generic, if not identical. The reservation is necessitated by the fact that we are dealing with conidial forms.

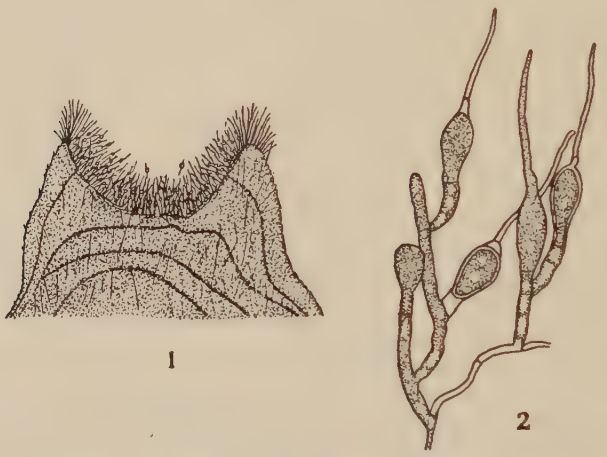
Patouillard noted that the cups of *Michenera artocreas* sometimes arose from the stroma of a *Corticium*, the hyphae of the two being identical, and continuous from one to the other. Hence he concluded that *Michenera* is a conidial form of a *Corticium*.

In the United States, *Michenera artocreas* usually grows in association with *Corticium subgiganteum* Berk. The *Corticium* occurs on the under side of the host branch, and the *Michenera*, when present, on the upper. On fallen branches, if the *Corticium*

happens to lie uppermost, *Michenera* cups may appear, arising directly from the hymenium, fused with the tissue of the *Corticium*, the hymenium of which overruns the bases and sides of the cups.

Pierce (1890) examined herbarium specimens of *Michenera artocreas*, and decided that it was a conidial stage of a *Corticium*, but that it was not related to the adjacent hymenia. Subsequently, Lyman (1907) re-investigated the question, and established that *Michenera artocreas* is a conidial form of *Corticium subgiganteum*. The details given here, concerning the North American fungus, are taken from Lyman's account.

Corticium subgiganteum is effused, rather tough, white, becoming corky and brownish when dry. The basidia are clavate,



Text-fig. 1. *Michenera artocreas* (after Lyman). 1. Vertical section of stroma. 2. Conidiophores with developing conidia.

40 × 14·5μ, and the basidiospores globose, apiculate, 19 × 14μ. Massee referred it to *Peniophora*, but Lyman retained it in *Corticium*.

Michenera artocreas, according to Lyman, is cup-shaped, 3–20 mm. diameter, with white or brownish sides and a projecting rim, the cup being nearly filled with reddish brown spores adherent in a solid mass which becomes hard and cracked when dry. The cup may be solitary, or clustered, or more or less fused. In section they show three distinct regions—the sides and base of interwoven hyphae, the hymenium lining the cup, and the brown mass of spores which frequently fills the cup. The tissue of the cup is loose and spongy, and may show brownish layers which indicate periodic stoppages of growth.

"The first appearance of the cup is a small pyramidal growth

of hyphae, faintly brownish tinted on the exterior. A longitudinal section frequently reveals concentric brownish layers which mark the successive periods of growth in the intermittent development of the pyramid. The hymenium originates at the apex of the pyramid, where the hyphae begin to form spores and a brown spot appears. This spot becomes sunken, due to the continued upward growth of the surrounding sterile tissue to form the raised sides of the cup....The origin of the hymenium is superficial and its development is entirely gymnocarpic, for the cup makes its appearance by the continued upward growth of the tissue at the margin of the hymenium, not by the rupture of an originally closed vessel. The diameter of the fructification increases by the continued expansion of the hymenium, which develops not only in the bottom, but also up the sides to the margin of the cup."

The spores are terminal and solitary. They are ellipsoidal or lemon-shaped, with a persistent stalk and a long, slender, apical appendage. The ellipsoidal part is yellowish to deep reddish, thick-walled, 12–20 × 10–15μ; the stalk is about as long as the inflated part of the spore, 3–4μ diameter, paler in colour, and empty; the appendage is flexuose, hyaline, empty, 1·5–2·5μ diameter, and up to 75μ long. The sporophore may branch near the apex, so that a cymose cluster of spores is produced, while after the first spores have been formed, repeated basipetal branching occurs, either just at the bases of the spores or from lower parts of the sporophores. Numerous long, slender, hyaline paraphyses accompany the sporophores.

"The process of development of the spore is as follows. The end of a young sporophore, rich in protoplasm, enlarges to form the lemon-shaped spore. Meantime growth continues from the upper end of the enlargement to form the slender appendage or lash, which has about one half the diameter of the sporophore. As the spore approaches full size it is cut off from the sporophore by a septum some distance below the swollen portion, thus forming the stipe. The terminal appendage and the basal stipe become vacuolate and finally emptied of their protoplasm as it gradually concentrates in the body of the spore. The mature spore has a thick wall consisting of an epispore which is the wall of the original hypha and which also forms the walls of the stipe and the appendage, and an endospore which surrounds the inflated portion only. The endospore is formed during the period of concentration of the protoplasm. Therefore the stipe and the base of the appendage frequently show thin, curving, transverse septa, abandoned as the protoplasm shrinks inward, which belong to the endospore and mark the successive stages in the concentration of the spore's contents."

Lyman grew the *Michenera* form in pure culture from the basidiospores of *Corticium subgiganteum*, and from the conidia of *Michenera artocreas*, but he did not succeed in obtaining the *Corticium* form in culture.

Artocreas poroniaeforme B. and Br.

Artocreas poroniaeforme (Plate II, fig. 1) occurs sparingly in the jungle at Hakgala on fallen twigs, the identity of which has not been determined. During recent years it has occurred in abundance on twigs of *Cinnamomum Camphora* in the Hakgala Botanic Gardens, either on dead twigs attached to the tree, or more commonly on fallen twigs and prunings on the ground.

As usually collected, the fungus forms scattered hemispherical cups, up to 5 mm. diameter and 2·5 mm. high, erumpent from the branch. These are white, or slightly brownish on the exterior. At first the top is plane, slightly depressed below the rim of the cup, and usually reticulated with irregularly broken, brown lines. Such specimens have opened, and are about to liberate their spores, though the latter are not loose, but cemented together and to the wall of the cup in a continuous mass. The plane upper surface is not pulverulent, and the whole fungus is hard and compact when dry. During wet weather it absorbs moisture and expands slightly; the cementing substance softens, and the contents of the cup, which at this stage consist chiefly of spores, are washed out, or possibly removed by insects. When old, the cup is empty down to the base.

Vertical sections show that the wall of the cup is up to 0·5 mm. thick. It is hyaline in section, and consists of interwoven thick-walled hyphae, with lumina 1–2μ diameter. The exterior may be slightly tomentose with free ends of hyphae, 2–4μ diameter, thick-walled, or almost solid, irregularly curved sometimes bifurcating at the tips, sometimes dividing into a cluster of short, curved branches. In the context of the wall the limits of the hyphae are not discernible, their membranes being fused into a continuous mass, in which, on staining, the contents of the individual hyphae appear as widely separated, irregular lines. When a vertical section of the cup is placed in water, the wall swells and straightens out. As seen in section, the wall is horny when dry and subgelatinous when moist. In serial sections, the tissue of the wall is sometimes found to be interrupted in places by narrow gaps which extend completely through it horizontally and are filled by a loose weft of hyphae. The hyphae bear clamp-connections. The wall is not present over the base of the cup.

Vertical sections through a cup which is filled with spores show a peculiar structure (Plate III, fig. 1). From the host

tissue at the base of the cup there arise more or less vertically oval bodies, which may be aggregates of hyphae, or stout-walled sacs containing spores. In one large specimen, the masses at the base consisted of hyphae only and were small, up to 0·5 × 0·4 mm. in cross-section; above these were similarly shaped bodies, up to 1·2 × 0·6 mm., but with a stout sub-translucent wall, open above, and filled with spores. More usually, in open specimens, the basal part consists of closed sacs containing spores, while the upper part is formed of similar sacs open above. These sacs are loosely united to one another by hyphae, and the interspaces contain fragments of the bark tissue of the host. In the upper part of the cup the spores and the gelatinised remains of the walls of the sacs are fused into a continuous mass, while the fragments of bark form the brown reticulated network on the surface and thus mark the boundaries of the separate sacs.

The specimens from which the genera *Artocreas* and *Matula* were described are full-grown and open. Unopened examples are globose (Plate III, figs. 2 and 3), enclosed in a stout wall, except at the base. In these specimens, the sacs are, in general, in two layers, with a distinct zone of separation, partly filled by loose hyphae, in the equatorial plane. The sacs in the lower half arise from the host tissue at the base, those in the upper half are united to the upper part of the wall of the fungus. In general, all the sacs contain spores. In a horizontal cross-section the shape of the sacs is irregular (Plate III, fig. 5); their outline is variously lobed, and the lobes of adjacent sacs interlock without any definite arrangement. The fungus consists of a group of sacs, enclosed in a stout universal wall, with which the outer walls of the peripheral sacs are fused, while their inner walls are only loosely united to one another.

Dehiscence is first indicated by a depression at the apex of the sphere. Sections of such an example (Plate III, fig. 4) show that there is already a cavity in the upper part of the fungus, due to the gelatinisation of the walls of the uppermost sacs. The upper part of the wall then gelatinises, and the fructification expands, becoming widely open and cup-shaped, the gelatinised walls of the upper sacs and their spores forming a continuous mass which is hard and compact when dry. In this stage, parts of the walls of the sacs persist in the upper region, and closed sacs are present in the lower, more or less as figured by Massee. Subsequently the walls of the lower sacs are gelatinised, and all the spores disappear, leaving the empty cup.

Massee's generic description is obviously incorrect. The fungus is closed at first, but it is not closed by an epiphragm. He did not have any closed specimens. Further, the internal

tissue is not a gleba broken up into numerous loculi by dissepiments, but a group of sacs attached either to the host tissue at the base or to the wall, and loosely bound together elsewhere by hyphae.

The latter feature of the fungus is most remarkable. In a sense, the growth of the lower group of sacs is independent of the universal wall which later forms the cup. The fungus arises within the cortex of the host plant and forms a small pulvinate cushion which ruptures the epidermal layer. The hyphae of this cushion do not arise from the host tissue continuously over the whole of its base, but from a circular peripheral zone and from separate small areas enclosed by that zone. This is also evident when tangential sections of the host are taken over the area of attachment of the mature cup. One then finds that the sections consist of cortical tissue in which are embedded isolated groups of spores. Thus, the bases of the lower sacs are embedded separately in the cortex. It is therefore clear that the lower sacs arise from separate points of the host tissue distinct from one another and from the universal wall. Hence the hyphae from which these sacs are formed must arise from the host tissue in separate masses. The outer layer, or universal wall, of the fructification arises from a circular zone surrounding the points of origin of the sacs.

The fusion, or partial fusion, of these masses occurs before the fungus emerges from the cortex. In all cases the emerging pulvinate cushion presents a continuous surface. In small examples, there may be only one layer of sacs; the outer walls of the peripheral sacs are then fused with the universal wall, as are also the apical parts of the walls of the inner sacs. Interspaces, filled with loosely interlacing hyphae, are found, in such examples, only vertically between the sacs. In these cases, it would appear that the hyphae of the universal wall form a tissue continuous with the upper parts of the sacs during the whole period of development of the fungus.

In larger examples, however, the sacs are situated more or less in two layers, the lower arising from the host tissue at the base of the fungus, and the upper united to the universal wall, with interspaces between the two layers. In these examples, it would seem that the sacs first formed are attached to the upper part of the wall and are succeeded by others from the host tissue within the base as the fungus increases in size.

The independent initiation of the sacs at the base of the fungus explains the presence of bark fragments in the mature fructification. As each group of hyphae emerges from the cortex, it pushes up pieces of the overlying tissues, and these are retained between the sacs. The fact that these fragments are found

between the two layers of sacs in the larger specimens favours the view that in such examples the basal sacs succeed the upper.

In some slides, however, the vertical section of an unexpanded specimen clearly shows a small immature sac arising from the upper part of the universal wall and pushing between two mature sacs. Hence, the sacs can arise from the wall as well as from the host tissue at the base.

Frequently the fungus does not form a cup. Minute pulvinate examples, about 1 mm. diameter, which barely emerge from the ruptured cortex, may contain mature spores. In these the upper layer disappears, leaving a shallow cavity filled with spores.

Text-fig. 2. *Artocreas poroniaeforme*. 1. Conidiophore. ×600. 2. Germinating conidia. ×250.

The sacs are completely filled by the conidia and conidiophores. The conidiophores arise from the wall of the sac, and are hyphae of varying length which bear conidia terminally and laterally. The apical conidium is the first to be formed; consequently the mature spores are found at first in the centre of the sac and the immature spores towards the periphery of the spore mass. The conidiophores and conidia adhere strongly to one another and form a solid mass, so that it is practically impossible to tease out or separate the contents of an unopened sac in order to ascertain the mode of production of the conidia. But in open sacs, where gelatinisation and deliquescence of the older conidiophores has begun, immature conidiophores may be isolated. Paraphyses have not been observed.

The conidiophores are 4–6μ diameter, with a thick wall, and

a narrow lumen, 1–2μ diameter. The immature conidium, on staining, appears obclavate or obpyriform, but this is only the shape of the cell contents. The wall of the spore is thick, and usually fused with adjacent structures, so that its outline is not evident. The general shape of the immature spore is elongated oval, often irregularly oval, the thickness of the wall varying from point to point.

The terminal spore is produced first. Others are subsequently produced basipetally on short lateral branches. Sometimes these arise close below the terminal spore, so that a cluster of conidia results. The cell contents increase in size and form a spherical mass situated towards the base of the spore, and this mass then acquires a thick wall independent of the wall of the parent cell. The spores are liberated by the deliquescence of the wall of the parent cell. At first, shreds of the latter may remain attached to them, and their outline appears irregular, but they subsequently become quite smooth.

The mature spores are hyaline, spherical, 16–20μ diameter, with a wall 1·5–2·5μ thick. In some sections of the fungus, stained with Haematoxylin or Bismarck Brown, a few of the spores are black; these latter have granular contents which appear to be disorganised. With Gentian Violet, the immature spores are strongly stained, but the mature spores do not take the stain.

In the immature fungus, the internal tissue is dull yellow and subgelatinous. When the spores are mature, it becomes opaque.

In its conidiophores and the mode of formation of the conidia, *Artocreas poroniaeforme* resembles *Michenera artocreas*. In both the conidia are produced basipetally, and are formed within a spore mother cell. In the latter species, the wall of the mother cell persists as an apical appendage and a basal pedicel, but in *Artocreas poroniaeformis* this wall gelatinises and disappears, leaving the spore spherical.

On the other hand, the general structure and mode of development of *Artocreas poroniaeforme* is quite different from that of *Michenera artocreas*, and the two cannot be regarded as co-generic. In that respect, Massee's conclusion was correct, but it would seem doubtful whether he was justified in rejecting Berkeley and Broome's generic name, *Artocreas*.

Both Pierce and Patouillard suggested that the spore of *Michenera* was a chlamydospore. This question was discussed at length by Lyman, who noted that the formation of the spore was similar to that of a chlamydospore in that the protoplasm shrank into the central portion of the cell, leaving empty walls above and below.

Lyman pointed out two distinctions between the *Michenera*

spores and ordinary chlamydospores. In the first place, the *Michenera* spore is normally formed in a terminal cell, not in any cell, and the empty portions of the parent cell are differentiated into a stalk and an appendage which persist as permanent parts of the spore. But he noted that in some *Michenera* spores the appendage was absent, while in other cases it grew out as a hypha, "perhaps" with the formation of other spores beyond, so that the spore was intercalary like an ordinary chlamydospore.

The second distinction is that the *Michenera* spores are grouped in definite fructifications. In this connection Lyman stated that "No such condition is known in the case of undoubted chlamydospores, but the nearest approach is found in *Nyctalis*, *Ptychogaster*, and *Fistulina*, where extensive chlamydosporic fruit bodies are formed, though there is no definite hymenium and the fructifications are formed through the usurpation by the chlamydospores of what were primarily basidiosporic fructifications."

Lyman concluded that it seemed impossible to avoid classing the spores of *Michenera* as chlamydospores, since their method of formation is chlamydosporic.

The method of spore formation in *Artocreas poroniaeforme* is the same as that in *Michenera artocreas*, but no part of the wall of the parent spore persists. Intercalary spores have not been observed in *Artocreas poroniaeforme*. The constant character of the conidiophore and conidia would appear to distinguish these spores at least from chlamydospores, as usually understood. If they are to be classed as chlamydospores, then all "endospores" must be similarly regarded; and though the mode of formation may be similar, there does not appear to be anything to be gained by thus extending the usual conception of a chlamydospore.

Matula Rompelii Rick.

Specimens of *Matula Rompelii*, which was described by Rick from Brazil, have been kindly furnished by Mr C. G. Lloyd. In general appearance the open fungus is identical with *Artocreas poroniaeforme*, though slightly different in colour. It was described as yellow. The cups, in the available specimen, are up to 4 mm. diameter and 2·5 mm. high, minutely tomentose externally. The spores are spherical, 16–19μ diameter, with a wall up to 3μ thick. The specimens are in an advanced stage, but they show the remains of the walls of the sacs at the base, and in one a closed sac, filled with spores, was found.

The spore mass is more friable than in the Ceylon species, but, nevertheless, the spores are held together by the disorganised

remains of the conidiophores, etc., when the mass is sectioned. The wall of the cup arises in a ring, as in the Ceylon species, but there is, in the specimens examined, a thin continuous layer, about 12μ thick, overlying the host tissue and forming a basal layer within the cup. A few cortical cells of the host plant occur in the tissue of the lateral wall of the cup near the base, but these do not appear to occur between the sacs. This difference from the Ceylon species may be due to a difference in the host plant, or, more probably, to the presence of a basal layer of hyphae within the cup.

Matula Rompelii is co-generic with *Artocreas poroniaeforme*, but it is doubtful whether it is identical. The two differ in structure as regards the base of the fungus, though this difference may not be constant. But both are conidial forms, and it is probable that they are conidial forms of different species.

Peniophora Habgallae (B. and Br.) Cooke.

Peniophora Habgallae Cke. (Plate II, fig. 2) also occurs on fallen Camphor twigs at Hakgala. This species is white, subtranslucent, saucer-shaped or pezizoid, circular or oval, regular or slightly lobed, up to 1·5 cm. diameter. The upper surface is plane or undulating, with a sharp definite margin, from which the convex sides curve backwards slightly into the flat base, which is erumpent from the host plant only over a central area. In some examples the base is contracted into a short broad stalk. When fresh, the fungus is up to 3 mm. thick, but in drying it shrinks into a thin disc, 0·5–1 mm. thick, the lower surface then becoming concentrically grooved. The hymenial layer is white, or pallid with a white margin, fleshy, about 0·15 mm. thick, and the cortex at the sides is white, rather loosely built, about 0·1 mm. thick. The internal tissue is subgelatinous, and the fungus is fragile when fresh. The cystidia are hyaline, flask-shaped or conical, encrusted with a slightly thickened wall, 80–100μ high, 14–20μ diameter below. The spores are oval, smooth, hyaline, 16–21 × 12–14μ.

Peniophora Habgallae occurs on the lower side of the Camphor twigs, and *Artocreas poroniaeforme* on the upper side.

At first sight, these two species do not appear to have any relationship to one another. But on cutting vertical sections of the *Peniophora*, especially of the examples which arise from a pseudo-stalk, it is found that the structure of the base of the *Peniophora* is exactly the same as that of the *Artocreas*. The internal tissue at the base of the *Peniophora* consists of ovoid masses, loosely united by hyphae, with fragments of the cortical tissue of the host between them (Plate III, fig. 6). They are identical with the sacs of *Artocreas*, but, so far as has been

observed, they do not contain any spherical conidia. The walls of the sacs are interrupted above, and the hyphae grown out and intermingle to form the continuous context of the *Peniophora*. This structure is not universal; in some examples the fungus grows out directly from the host without forming separate masses of hyphae internally.

In the case of *Corticium subgiganteum*, examples occur in which the *Corticium* and the *Michenera* fructifications are combined. I have never found that state in *Peniophora Habgallae*. The *Peniophora* and the *Artocreas* fructifications are, so far as has been observed, always separate.

Cultures.

When Camphor twigs bearing *Peniophora Habgallae* only were placed in a closed glass dish with the *Peniophora* uppermost and kept moist, white globose bodies, up to 3 mm. diameter, developed on the hymenium of the *Peniophora*. These were composed of uniform hyphal tissue internally, and they became covered by a hymenial layer which contained typical *Peniophora* cystidia and immature basidia (?). Spores were not produced. The same occurred when other twigs were placed so that the *Peniophora* was on the under side.

Twigs bearing *Artocreas poroniaeforme* only, when similarly treated, produced similar globose *Peniophora* stromata on both the upper and the lower side, independently of the position of the *Artocreas*. The *Peniophora* stromata developed both on the bare side of the twig and among the *Artocreas* fructifications. But no growth occurred from the *Artocreas*.

Specimens of *Peniophora Habgallae* were collected at the beginning of August 1924. It was not found possible to obtain spore deposits from these, and consequently tissue cultures were instituted on maize meal agar. These developed a white fleecy mycelium. Transfers of mycelium were made to tubes of maize meal agar and to sterilised Camphor twigs in Roux tubes. The twigs were cut from living branches, sterilised by boiling three times and then autoclaved in the tubes.

On maize meal agar slants, the mycelium developed white globose bodies, up to 3 mm. in diameter. These were of uniform structure internally. They did not bear cystidia or basidia, or any form of spore.

In the Roux tubes, the mycelium grew superficially over the Camphor twig, covering it with a white film, and globose bodies, similar in appearance to those on maize meal agar slants, were produced on this mycelium, chiefly at the upper end of the twig. These cultures, which were begun on September 14th, were not examined until December 21st, and they had dried out in the

meantime. On examination it was found that these were identical in structure with immature *Artocreas*, and some of the sacs contained spores.

In these culture specimens, the universal wall is thin and not sclerotioid. The internal tissue is dull yellow and subtranslucent in section, and traversed by white veins which consist of the loose hyphae between the sacs. In immature specimens of *Artocreas poroniaeforme*, naturally developed, these veins appear brown, because of the inclusion of fragments of bark, but no bark fragments were found in the culture specimens, no doubt because these developed from superficial mycelium, not from within the cortex. Numerous spore mother cells were present in some of the sacs, but few spores; and the latter were, in general, thin-walled, only one or two having a wall up to 1·5μ thick. Some of the spores were much larger than in nature, and attained a diameter of 32μ.

The typical cup-shaped fructification was not obtained. Similarly, Lyman did not obtain the cup of *Michenera artocreas* in his cultures. Under the conditions of the cultures, the walls of the hyphae were not thickened, nor, in general, was the wall of the conidium. But there can be no doubt, from the structure of the fructification and the mode of formation of the spores, that these examples are *Artocreas poroniaeforme*.

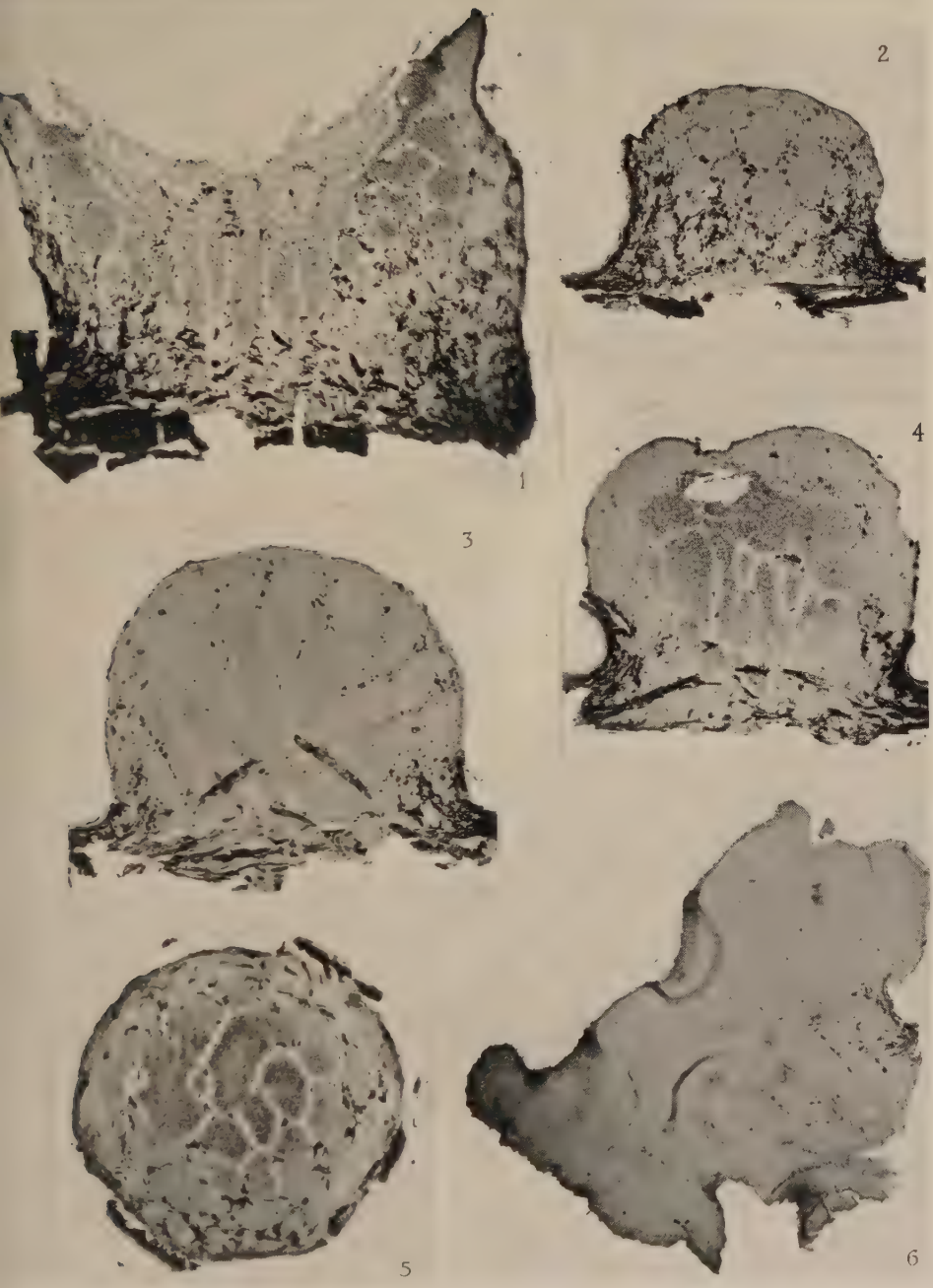
Recently developed specimens of *Artocreas poroniaeforme* were collected in December 1924, and spores suspended in hanging drops of water, maize meal agar, Raulin agar, and Naegeli agar in damp cells. Germination was observed only in drops of the two last-named, which had been allowed to dry out in twenty-four hours and then re-wetted; these spores germinated two and a half days later. Similar treatment of the water and maize meal agar drops did not induce germination. The germ tube emerges through a minute perforation in the thick wall and at first is oval or irregularly lobed. Subsequently it develops into a stout hypha, about 4·5μ diameter. Transfers of these germinated spores to maize meal agar were unsuccessful owing to contaminations.

Conclusions.

The cultures prove that *Artocreas poroniaeforme* is a conidial form of *Peniophora Habgallae*, as was suspected from the association of the two fungi and the similarity of the structure of the base of the *Peniophora*, in some examples, to that of the *Artocreas*. *Artocreas poroniaeforme* consequently affords a parallel to *Michenera artocreas*, which has been shown by Lyman to be a conidial form of *Corticium subgiganteum*.

Fig 1.

Fig. 2.


1
2
3
4
5
6

The mode of formation of the conidia in *Artocreas* and *Michenera* is the same. In each, the conidium is formed in a spore mother cell, and the successive spore mother cells are produced basipetally on the conidiophore. But in *Michenera* the wall of the mother cell persists and forms an appendage, while in *Artocreas* it gelatinises and disappears.

The structure of the fructification of *Artocreas* is, however, quite different from that of *Michenera*, and the two genera cannot be combined.

It would appear that Berkeley and Broome's name *Artocreas* should stand, its withdrawal having been due to the mistaken supposition that *Artocreas* was identical with *Michenera*.

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EXPLANATION OF PLATES II AND III.

PLATE II.

Fig. 1. *Artocreas poroniaeforme.* ×½.
Fig. 2. *Peniophora Habgallae.* ×½.

PLATE III.

Fig. 1. Vertical section through an open specimen of *Artocreas poroniaeforme.* ×12. The dark irregular bodies are fragments of bark.
Fig. 2. Vertical section through a small immature unopened specimen. ×15.
Fig. 3. Vertical section through an unopened specimen, nearly mature. ×15.
Fig. 4. Vertical section through a specimen just about to expand. ×15.
Fig. 5. Horizontal section through an unopened specimen. ×20.
Fig. 6. Vertical section through a stroma of *Peniophora Habgallae.* ×15. The two thick curved bands are due to folds in the section.

THE TOXICITY OF THE SPORES OF TILLETIA TRITICI TO ANIMALS*.

By Norman Dobson, B.Sc., M.R.C.V.S.

THE possible toxicity of grain damaged by bunt or smut (*i.e.* infected with the spores of *Tilletia Tritici* or *Ustilago* sp.) when fed to animals has been the subject of considerable controversy and references in the literature which have a bearing on the point are peculiarly contradictory. The question, apart from its scientific interest, is one of considerable economic importance. In view of the fact that Professor J. Russell Greig had observed an apparent connection between the presence of the spores in the tissues of dogs and the occurrence of epileptiform convulsions in these animals (4) it was considered desirable that feeding experiments under strictly test conditions should be instituted. An application was therefore made by Dr Malcolm Wilson and Professor Greig to the Board of Agriculture for Scotland for a grant in aid of the expenses of such research, and in June, 1924, I was entrusted with the prosecution of the work under their supervision.

By the kindness of Professor W. Wright Smith and Principal O. Charnock Bradley, adequate facilities were provided for the investigation at the Royal Botanic Garden and at the Royal (Dick) Veterinary College, Edinburgh, respectively.

Tubeuf (11) states (p. 306) that certain diseases are produced in animals by the consumption of spores of smut fungi with food and *Tilletia Tritici* is considered as one of the chief causes of these troubles. "The symptoms in the few cases of disease observed do not agree very closely. A paralyzing effect on the centres of deglutition and the spinal cord seems to be regularly present. As a result one generally finds a continuous chewing movement of the jaws, and a flow of saliva, also lameness, staggering, and falling. Cattle, sheep, swine, and horses are all liable to attack."

Liskum and Krastavizky (7) fed up to 10 grams of spores of *Tilletia Tritici*, and *Ustilago Maydis*, daily to guinea-pigs, mice, rabbits, and a dog. During the experiment no injurious effects were seen, and all the subjects developed more or less normally. *Post mortem* examinations, however, showed that all their organs were attacked by the spores, and partially destroyed. The typical symptoms noted were, hyperaemia of the digestive tract, dark or grey coloration of the mucous membrane of the intestines, and stomach, and hyperaemia of lungs, kidney and

* I am indebted to the Board of Agriculture for Scotland for a grant to defray the expenses of this research.

brain. The spores were found to have accumulated especially in the adrenal bodies and the blood vessels were so full of the spores, that they sometimes burst from obstruction. In one case, the writers observed that they had penetrated the placenta, and reached the tissues of the foetus. It was noted that there was almost always a disproportion between the number of spores and the pathological changes. The conclusion arrived at was that the spores of *Tilletia Tritici* and *Ustilago Maydis* are injurious to animal organs, though their effects may not always be visible externally.

Lindau in Sorauer(9) doubts the toxic effects of the spores of *Tilletia Tritici*, as he quotes the records of Staes, who noted that a farmer regularly fed his horse and cattle with waste meal, in which a very large quantity of the spores was present. The meal was always soaked in water twenty-four hours before being used for feeding, and as this probably caused most of the spores to germinate they would be killed by passage through the intestines. Lindau evidently considers this a proof that the spores of *Tilletia Tritici* are not injurious to animal tissues. It would appear that he was mistaken in assuming that such immersion was sufficient for germination as Riehm(8) found that three or four days in diffused light at a temperature of 20° C. was required: direct sunlight or total darkness delayed germination, as also did temperatures below 20° C. In the present experiments it was found that in summer time under diffused light, at the ordinary temperature of the laboratory, six or seven days were required for germination.

It would seem that if spores were fed to animals in a germinated condition, there would be a greater possibility of any toxic substance being absorbed by the animal tissues, owing to the rupture of the hard spore case. When examining the faeces of the experimental animals, it was extremely rare to find any of the spores ruptured. Only in the specimens from the guinea-pig and the rabbits were broken spores found, and presumably this occurred during the process of mastication, due to their fine molar teeth. In no case was there any sign of germination of the spores found in the faeces.

Baudys(1, 2) gives a graphic account of his experiments upon white mice, fowls, rabbits, and himself, although he does not state definitely the weights of the spores administered to the animals or to himself. In view of negative *post mortem* findings, and the fact that he did not experience any discomfort from taking a feed of 9·5 grams of the smutted wheat mixed with wheat meal, he concluded that the spores are not poisonous. Klimmer(6, p. 138) refers to the work of Albrecht, "in a case where fifty-one head of cattle fed on wheat chaff infected with

Tilletia Caries, Puccinia graminis, and *Pleospora herbarum,* eight beasts were taken ill, and three died." The symptoms were—spasms of the muscles of mastication, weakness with anaesthesia in the lumbar region, and fever; inflammation of the conjunctiva, mucous membrane of the nose, and upper air passages; urgent desire to urinate, and tenesmus; on *post mortem,* gastro-enteritis with erosion was found.

Greig(4), in 1922, published a report of three cases which he had attended of epileptiform convulsions in the dog, which appeared to be associated with the spores of *Tilletia Tritici.* "The symptoms were identical in each case. The animal was suddenly attacked by a series of convulsions, which continued for some hours, and terminated in coma; in two cases death resulted, but in the other case recovery took place, though the animal was subsequently destroyed."

In case *A* the faeces contained a very large number of spores of *Tilletia Tritici.* An examination of the abdominal organs was made *post mortem,* but no definite abnormality was found.

"In case *B* the faeces contained large numbers of the spores, which were found on *post mortem* to be present throughout the alimentary tract; they were also very numerous in the bile and urine, which in this case were examined microscopically. The brain unfortunately was not examined, and no definite microscopic lesion was discovered in any other organ.

"In case *C*, spores were present in large numbers in the intestine and urine. No definite lesion was remarked until the cranium was opened, when an acute cerebral meningitis was observed; smear preparations from the cerebral cortex again revealed the presence of the spores. In sections cut from the brain, kidney, liver and spleen the blood vessels were seen to contain very large numbers of dark pigmented bodies; these showed much variation in size, ranging from mere particles of pigment, to bodies 12μ in diameter; their nature is yet to be determined. Since the spores were so numerous in the urine, it was expected that they might also be present in the blood stream. No spores have, however, been seen in sections of tissue containing blood vessels, and it is possible that these pigmented bodies may represent spores in a state of disintegration; on the other hand, they may be mere artefacts."

Greig pointed out that the spores of *Tilletia Tritici* were frequently present in the faeces of normal dogs, but in many cases lengthy search was required before a single spore could be demonstrated, whereas in the faeces of affected cases, commonly six and not infrequently twelve spores could be seen in a single field. He suggested that although his material was insufficient to permit of any definite conclusion, it appeared

probable that on occasion the spores of *Tilletia Tritici* might constitute a factor in the production of epileptiform convulsions.

The preliminary work of the present investigation consisted in the examination of normal dogs with the object of determining the incidence of the spores of *Tilletia Tritici* in the alimentary tract. Three hundred and fifteen patients at the Royal (Dick) Veterinary College, were examined, and among these there was, of course, a wide diversity of breed. A large percentage were house dogs of the city, but there were also a large number of sporting dogs of various breeds.

Methods of Collection.

The method of collection, chiefly consisted in direct removal of the faeces from the rectum. In some cases, where faeces had recently been passed in the kennel, a sample was taken from the centre of the stool, transferred to a sterile Petri dish, and emulsified in normal saline solution. With a glass rod, dropping the same quantity constantly, some of the emulsion was transferred to a microscopic slide, and covered with a $\frac{7}{8}$ in. square cover slip. The entire $\frac{7}{8}$ in. area was examined and a record kept of the number of the spores found. Two such preparations were made at each examination of faeces. During the early part of the experiment spores were found only in small quantities in the faeces, whereas towards the close of the feeding period the $\frac{7}{8}$ in. area showed the presence of seven to eight hundred spores in almost every examination.

The dog was examined as early as possible after its arrival at the hospital, again on the second day after admission, and subsequently according to the length of time it was a patient in the hospital. Only in two cases were spores of *Tilletia Tritici* found in the faeces of new arrivals, whereas when the dogs had been in hospital two days, it was found that 26·6 per cent. were passing the spores in their faeces.

The bedding of the canine patients in the College consists of wheat straw and sawdust. Systematically on arrival of the wheat straw at the hospital from the forage merchant, washings were made and centrifuged. Examination of these microscopically showed the spores very often present, especially in the months of July and December, 1924, and during these months, examination of the faeces from the patients, showed heavy infestation. During the months of June, August, September, October, and November the washings of wheat straw showed a less gross infestation, and the examination of the faeces showed a similar decrease.

Periodic microscopic examinations were made of the foodstuffs given to the dogs. The biscuits seemed a likely source

of infection, but spores were not found in these. Washings of the coats of the dogs gave positive results, and large numbers of spores were found during the months of heavy infection of the bedding.

One therefore must assume, that in these cases arriving at the hospital quite clear of infection and which in two days were found to be passing spores in their faeces, infection occurred through wheat straw contamination of food placed in a shallow bowl on the floor of the well-bedded kennel.

Experimental Animals: Housing and Feeding Arrangements.

Of three rooms at my disposal, in addition to the research laboratory, one room was utilised as a food preparation room, and the remaining two for the accommodation of the experimental animals. These were all admirable rooms, with concrete floors, washable walls, well lighted and ventilated. The experimental animals were two dogs, eight rabbits, eight guinea-pigs and, later, four fowls. The dogs were accommodated with benches well supplied with sawdust, and had the use of one room. The rabbits, guinea-pigs and fowls were kept in individual cages fitted with zinc trays, and a thick bedding of sawdust. The cages were placed on benches and one side of the cage was fitted with a zinc plate preventing the passage of food, etc., from one cage to the next. The dogs, rabbits and guinea-pigs were kept three weeks before the special feeding commenced, and the examination of the faeces during the whole period showed every animal to be quite free from infection with the spores of *Tilletia Tritici*.

Controls.

One rabbit and one guinea-pig were used as controls. They were kept under precisely similar conditions to those of the other animals, with the one exception, that they received no spores.

From the date of arrival of the animals until May 3rd, 1925 (a period of nineteen weeks), when the fowls had to be placed in the same room as the rabbits and the guinea-pigs, the faeces of the controls were quite free from spores. Periodical sweepings were taken from the ledges and window-sills and examined for spores but always with negative results until the arrival of the fowls, and then, presumably as a result of their constant scratching in the cages, spores were found very occasionally in the faeces of the controls and in the sweepings of the ledges, etc.

This condition might be contrasted with that prevailing in the workroom where the experimental animals were kept by

Baudys(2). He describes the atmosphere as saturated with the spores, causing irritation to mucous membrane of nostril and sneezing.

Feeding Arrangements.

The food was prepared in the room specially set apart for the purpose. The ears of wheat were previously examined and bunted grain detached. The diet of the dogs consisted of unbroken biscuit in the early morning and at four o'clock in the afternoon they were given broken biscuits over which had been poured the liquid from boiled meat with a little minced meat added. This gave a moist mixture and with the aid of forceps the bunted grains were introduced under the surface of the food in the bowl and crushed, releasing the spores from the grain without contaminating the atmosphere. The rabbits and guinea-pigs were given a few oats with greens and roots in the early morning; the afternoon feed consisted of moistened oats with the spores added as detailed in the case of the dogs.

Tabulated Results of Experiments.

1. Number of days the spores were fed to the animals.
2. Total quantity of spores fed (in grams).
3. Weight (in grams) of animals when special feeding began.
4. Gain or loss in weight (in grams) during the period.

Animal	1	2	3	4	
Dogs.				Gain	
DA	136	100·62	No facilities for weighing		
DB	137	103·57			
Rabbits.					
RA	14	·375	1558·6	259·8	
RB	142	54·00	1488·7	941·3	
RC	49	3·50	1671·8	147·2	
RD	107	15·007	1507·0	798·0	
RE	120	21·32	1464·4	719·4	
RF	149	85·00	1388·8	975·2	
RG	172	Control	1067·5	890·0	
RH	28	1·25	1499·5	108·8	
Guinea-pigs.					
PA	14	·375	435·2	40·4	
PB	162	Control	657·6	316·0	
PC	119	20·60	500·8	180·0	
PD	149	85·00	341·6	302·01	
PE	50	3·64	443·5	156·50	
PF	137	40·43	586·7	105·69	
PG	28	1·03	565·7	41·3	
PH	106	14·7	559·7	164·59	
Fowls.				Loss	
FA	31	36·82	1040·54	52·54	
FB	52	207·00	1360·18	96·75	
FC	52	207·00	1476·13	48·67	
FD	19	11·80	1101·22	259·21	—Roup case.

Condition of the Animals during the Experiment.

The health of the dogs, rabbits and the guinea-pigs was excellent throughout the period. The animals all gained weight and no abnormal symptoms were seen. All remained keen for food until the dosage reached 5 grams daily and then occasionally some inappetence was shown which could be attributed undoubtedly to the obnoxious, but very characteristic odour, of the *Tilletia Tritici* spores, the "herring brine" odour due to the presence of trimethylamin.

Four fowls were purchased on May 2nd, 1925, and as the faeces showed no sign of spores the special feeding commenced at once. Two of the fowls were fed with 10 grams of the spores of *Tilletia Tritici* per day for the ultimate fourteen days of the feeding experiment and showed no pathological symptoms. Fowl FD was killed on May 23rd owing to the occurrence of roup which developed on May 16th, after nineteen days special feeding: it showed the characteristic lesions on the comb, wattles and mucous membrane at the commissures of the mouth.

It is interesting to note that according to Heald(5) each smut ball contains from six to nine million spores. From experience it was found that the average of fifty-six smut balls to the gram was common and therefore the mass infection with the spores can be seen at a glance from the above table.

Post Mortem Findings.

The *post mortem* examinations revealed healthy organs in every case. In the animals that had been subjected to feeding for a month and more fat was found in the usual fat deposits in large quantities. Urinary and gall bladders, after ligature, were removed to sterile Petri dishes and here incised and the contents collected. Examinations of the bile and urine for spores in all cases proved negative. The stomach and intestines were quite normal, there were no petechiae, haemorrhagic patches or discoloration on the surface of the lungs or on any other serous membranes, and the kidneys, adrenals, spleen and brain were all normal. The blood was carefully examined, both from the heart and from the peripheral vessels, and found to be free from spores and no sign of rupture of the blood vessels was detected. Portions of the various organs were removed and fixed in Flemming's weak solution or in Pick's solution, passed through the usual processes, embedded in paraffin, and serial sections made and stained with Mayer's haem-alum. Examination of these sections proved entirely negative; the spores of *Tilletia Tritici* were not found in any cells, blood vessels, or

embedded between tissue cells, in any organs, neither was any cell destruction found.

The only two animals that became pregnant were guinea-pig PH and rabbit RF. Guinea-pig PH aborted on February 1st, 1925, after being under test since December 22nd, 1924, and must have been mated prior to this date. Rabbit RF was mated on May 1st, 1925, and destroyed June 11th, 1925, when five full-term young were found. In neither of these cases could the spores of *Tilletia Tritici* be found in the foetal membranes or in the organs of the foetuses. In all the fowls large deposits of fat were found and the liver in the cases FB and FC was slightly fatty, otherwise all the organs appeared quite normal. The tissues of the fowls were examined microscopically with negative results and in none of the organs was cell destruction visible.

From the foregoing and the table giving the increase in weight of the different animals, it will be seen that the non-appearance of pathological symptoms is quite compatible with the perfectly healthy condition of all the animals during the experiment, their general appearance of healthy vigorous condition in life and negative *post mortem* results.

The loss of weight in the fowls may be accounted for by the fact that they had previously been kept in a large run permitting all necessary exercise and, when confined in a large cage, with great lack of exercise and little scratching accommodation, although the food was suitable, loss in weight resulted but the condition of the organs remained healthy. The loss in weight is not to be attributed to any toxic effect of the spores, but rather to the fact that the condition of these birds suffered from their confinement. One must also remember that, for a period of fourteen days, they were consuming ten grams of the spores per day; these were devoured eagerly, although their food value was practically nil.

The question arises whether the spores which have passed through the alimentary tract are again capable of causing infection. Tubeuf(12) has shown that the passage through the alimentary tract destroys the germinating power of the spore and therefore manure contaminated with spores when spread on the land does not infect the crop. Baudys(1) also came to the same conclusion. Steglich(10) considers that danger from spores introduced with stall manure lasts but a few days because, as he asserts, manure acts as a stimulant to germination and thus causes the spores quickly to become innocuous in the absence of a host plant. Dreger(3) states that grain infection is perpetuated in the manure. Several experiments were made with the spores that had passed through the alimentary tracts of

the various test animals during the investigation, but germination could not be induced.

Discussion and Conclusions.

Bunt of wheat has been known from very early times and is referred to by Theophrastus and other early Greek and Roman writers. Until 1775 it was believed to be caused by environmental or providential influences, but in that year Tillet proved its infective character by experiment. Much research has been carried out on the biology of this fungus and the subject still occupies a prominent position in economic botany. Under these circumstances, if the feeding of the spores to animals had commonly proved injurious, one would expect that more precise records of its toxicity would have been made. The early records of Tubeuf(11) and the findings of Liskum and Krastavizky(7) and Greig(4), who either found that the spores had penetrated the tissues or noted pathological symptoms associated with the occurrence in feeding stuffs, still remain. A possible explanation of their observations may be found in the assumption that such effects as they noted resulted from the occasional presence of an unknown factor which allows of the absorption and penetration of the spores.

The result of this investigation, however, taking into account the lengthy period of the test, the large quantity of the spores administered, the invariable health of the animals throughout the entire experiment and the negative *post mortem* findings, justifies the conclusion that only in the most exceptional cases can the spores of *Tilletia Tritici* be regarded as injurious to animals. This is in agreement with the later work of Tubeuf(12). From the point of view of the practical stock feeder, it may be safely accepted that grain infected with bunt may be fed without injury to animals.

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PSEUDOPERONOSPORA HUMULI AND ITS MYCELIAL INVASION OF THE HOST PLANT.

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(With 4 Text-figs.)

The Downy Mildew of the hop, *Pseudoperonospora Humuli* (Miy. and Takah.) Wils., first found in Europe in 1920(6) in the Experimental Hop-garden and Nursery at Wye College, Kent, is now so widespread in this country as to appear indigenous. During the subsequent years it has appeared to an increasing extent on wild hops and in cultivated hop-gardens generally, and has shown during 1925 that it is a menace to be seriously considered by the British hop-grower.

Since the autumn of 1924 it has been reported also in Germany, France, Belgium and Russia.

After the first description of the disease in England(6), papers were published(7,8) which deal more fully with the history,

effect, and economic damage caused, and with the parasitism of the fungus so far as it had then been investigated. A widespread and somewhat alarming appearance of the disease took place in hop-gardens in Kent during 1925 and observation was made of the habits and progress of the fungus in relation to its host from the time of earliest growth until the hops were picked. In the course of this investigation, new facts in regard to the mode of parasitism of the fungus were discovered and short notes were published (9, 10) concerning those details which were of practical importance, and a knowledge of which was likely to assist the grower.

One characteristic, though puzzling, feature of the disease is the production of more or less hypertrophied, "spike"-like shoots by the hop plant. These arise, commonly in company with other healthy normal bines, either from ground level (*i.e.* from the rootstock) or, later in the season, as stunted lateral branches at any height from the ground. They also occur at the tip of the main bine, which suddenly ceases growth and becomes "spike"-like, most commonly when it reaches a height of five to seven feet but sometimes at the top wire, twelve to fourteen feet from the ground. In the latter case and in that of the laterals, it is noteworthy that the remainder of the bine often appears perfectly healthy. On the leaves of such shoots, as well as on the surface of the stem, the mildew later produces its conidiophores in exceptionally dense masses often blackening the entire lower surface of the leaf.

The general appearance of the "spiked" growths suggested that they were due either to internal invasion by mycelium from the rootstock or to external infection by spores (8).

The economic damage caused by the hypertrophy of the shoots, so far as it had then been observed, was described in a former article (8) as negligible. We now know, however, that a very large proportion of the bines trained up in a hop-garden may be affected and may cease growth at a height of about five feet. Further, as regards spread of the disease by nursery sets, the opinion was expressed that in addition to the ordinary means of dispersal of the fungus, mycelium might be transported within the stems of young plants. Not only has such been found to be the case, but "spike"-like shoots have also frequently been seen in nurseries attached to hop-gardens.

In the spring of 1925 the existence of hibernating mycelium in the rootstock was hypothetical and the investigations here described were undertaken with the object of obtaining information on this and on other points.

The earliest observed occurrence of "spiked" growths in 1925 was in the experimental garden at Wye on April 18th.

After that date they were frequently found both there and in commercial gardens in the county. In one instance a "spike" was found arising from the rootstock of a wild hop in a hedge and later in the season, both in Kent and in Devonshire, a wild hop was found with most of the laterals and main bines in the "spiked" condition. This indicated that processes of cutting adopted in cultivation, could not be involved in the question as to the causes of production of the "spiked" growths.

Basal "Spikes."

The first material collected on April 19th cast a doubt upon the hypothesis of external infection. Arising from the rootstock of one hop there was a short "spike" 4·7 cm. high which had three pairs of small curled leaves protruding, the fourth pair not yet free from the protection of the stipules and the fifth pair still enclosed, with the remaining leaves, in the terminal bud. Conidiophores and spores were present in great numbers on all the leaves and even on the stipules and could be seen also within the loosely folded terminal bud. Zoospores emerged from the conidia when these were placed in water. Close by, arising from the rootstock actually in contact with the "spike" described, there was a shoot, six cm. high, having two pairs of leaves expanded and a terminal bud. The whole of this was perfectly healthy and the internodes were longer.

Two other "spikes" on a different hop plant were next examined. In both cases they were removed, together with portions of the rootstock, and were found to be arising from points close to other healthy bines. In one, by means of hand sections, mycelium was found to be present in the cortex of the stem from the top to the bottom as low down as the bases of the small brown bud scales; in the other an attempt was made to trace it further and even into the older rootstock but it was found no lower than in the former case, though in this instance it occurred in the pith as well as in the cortex. These spikes were respectively ten and thirteen cm. high.

On April 26th a "spike" was cut, with a portion of the rootstock, from each of two different hop plants. In the first specimen a close examination with a lens and with a microscope of scrapings of the leaves (seven in number) showed that the fungus was present in the form of mycelium only, in five of the upper leaves (including those no more than projecting from the terminal bud) and that in two lower leaves there were hyphae and young conidiophores (sometimes unbranched) with immature conidia. In the stipules at the four nodes at which these leaves were inserted in pairs*, only mycelium was found. Within the stem

* One of the leaves of the lowest pair was missing.

Fig. 1.

Fig. 2.

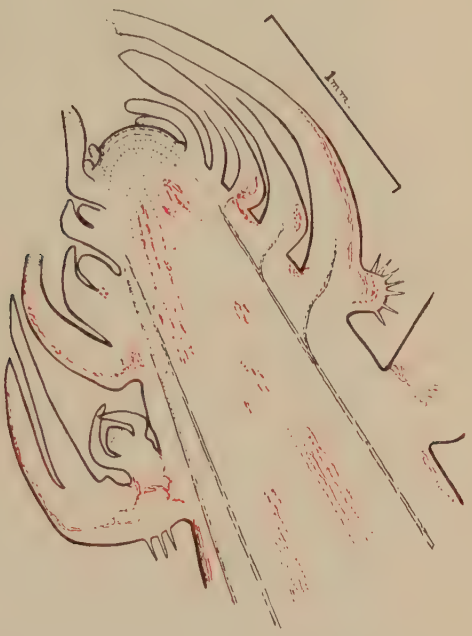

Fig. 3.

Fig. 4.

mycelium was present just above the junction with the older rootstock but could not be distinguished at any lower point. A longitudinal section cut half an inch below the node* of the lowest pair of leaves revealed mycelium in the cortex running longitudinally and extending from close to the bast to within two cell layers of the epidermis, and in one case the hyphae were seen extending along the inner walls of epidermal cells. The whole width of the pith was also occupied by the hyphae.

A longitudinal section was cut in the petiole of one of the lowest leaves and part of the main stem above and below the junction. Hyphae were found in both cortex and pith of the stem, extending to the next internode above and thickly invading the petiole. A bud in the axil, cut longitudinally, showed heavy infection of all its scales to the very tip, though it was as yet not elongated.

Examination of the leaves and stipules of the second spike, by means of a lens, showed that although dense masses of conidiophores might be present on a pair of leaves at a node, they were not necessarily present also on the corresponding stipules. The reverse was also found to be the case. Stipules may be found brown and withered as though killed by the mycelium. Internally, hyphae were again found in pith and cortex and were present at the extreme base of the spike; in this and in one further case, mycelium was found at the junction with the rootstock.

The presence of mycelium in one-year-old portions of the crown or rootstock was not discovered until the middle of May when a rooted set bearing four short shoots, all of which were "spiked," was examined. One of these shoots was extremely short (one and three quarter inches long) having probably been eaten off by slugs†. Mycelium was present within all, and in the shortest, nor far from its base, nine oospores were found in the pith. It was observed in this and in subsequent cases, that where an accumulation of hyphae occurs, there is commonly a separation of the host cells and in some stems there are gaps of considerable size.

Hyphae having been found for the first time definitely below the actual stem of the shoot of that year, in the cushion of tissue from which the shoot and a number of dormant buds arise, the whole rooted set (of previous year's growth) was split with a knife and longitudinal sections were cut in several places throughout its length of three and a half inches. Mycelium was

* This node was eight cm. above the junction with the rootstock and seven cm. from the tip of the terminal bud.

† The remaining three were five and a quarter, three and a half and three and a half inches long respectively and were not damaged except by the fungus.

found in abundance in pith, phloem and cortex and travelling radially in the medullary rays. The affected tissues were brown in numerous small areas (approximately three mm. diam.) and brown streaks were found in the wood. A break-down of the cortical cell walls was noticed.

One older set having portions representing growth of two previous years was examined and the mycelium was traced not only in the 1925 "spiked" growth, but also in the set of 1924 as far as its junction with the original 1923 set (*i.e.* one inch of woody 1924 growth).

These were the first two cases in which mycelium was observed in one-year-old tissue in addition to invading that of the current year's growth and they provided strong evidence that the mycelium was indeed perennial in the underground rootstock and had not merely invaded it in the course of the month or so during which active growth of the host plant had taken place above ground.

Terminal and Lateral "Spikes" on the Bine.

The production of "spiked" growths at higher level, took place later in the growing season and seems to have occurred practically simultaneously in different parts of the county of Kent*. During the second week of June, hops had reached a height of nine to twelve feet and plants attacked by the Downy Mildew were conspicuous by the fact that some, or all of the bines trained up had ceased growth after reaching a height of only five to seven feet. This phenomenon had been observed in previous years and has been described(7, 8), but an additional feature noted in 1925 was that bines stopped short in this manner often produce long and healthy laterals.

Bines were also observed which had apparently grown in a normal manner without any stunting at the tip, but which bore "spiked" laterals at one or more nodes.

For the purpose of investigating this stage of the disease whole bines were pulled from the hill and taken to the laboratory. Several were examined in this way and notes made as regards length, number of nodes, number and position of laterals, external signs of the fungus and its internal position. In some instances the terminal "spikes" themselves were cut off for examination with the microscope.

The first bine examined, which is typical of others, was that of a male hop, ten feet five inches long, and, at six feet two inches

* In addition to their occurrence at Wye on June 10th, three enquiries on that day, concerning their sudden appearance, were received from growers in Kent who reported that only two or three days previously there had been no sign of arrested growth.

from the ground, there was one pair of "spiked" laterals (in this case male inflorescences) arising from the eleventh node. The rest of the plant, above and below this node appeared quite healthy, with the exception of a few angular spots on the leaves at the sixth node (one foot eight inches above ground).

The pair of laterals immediately below those noticed (at the tenth node) were nine inches long, whereas those diseased measured only two inches. At the next node above (twelfth) the healthy laterals were five and a half inches long. The internode above was eight inches and that below was ten and a quarter inches long. At the eleventh node itself, the petioles of the subtending leaves were thick and short, and there were yellowish patches on the upper surface of the laminae and corresponding areas black with masses of conidiophores, on the lower surfaces. These were the only two leaves on the whole bine to show such symptoms of disease. By means of sections cut longitudinally through the node mycelium was found in the pith, phloem and cortex of the main bine, in the petioles of the two leaves and in the lateral shoots in their axils. It was noticed that the extent of the mycelium was marked by a brown discoloration of the pith, which in healthy areas is pure white. By splitting the main bine, it was found that the brown discoloration extended 2·4 inches below the node examined and presence of mycelium to a distance of 2·0 inches, but no lower, was confirmed. The pith of the laterals and of the two leaf stalks was solid; that of the node nearly solid, *i.e.* with a very small passage at the centre, and that of the internodes hollow. Above the affected node the pith was brown and mycelium was traced to a distance of three and a half inches. Above this point the pith was white and no mycelium was found until the next node but one (thirteenth) was reached*. Here again there was a brown discoloration, with mycelium, over a length of one inch below and one inch above the node. This node was at a height of seven feet six inches from the ground and thence upwards there was no mycelium though search was made through two feet ten inches of bine to the growing point at ten feet five inches from the ground. Sections cut longitudinally through the thirteenth node showed mycelium running in the pith and cortex of the main stem and into the pith of leaf petioles and of lateral shoots (male inflorescences), although neither of these as yet showed any outward sign of disease. In the lateral shoots mycelium was traced through four inches of their total length of five and a half inches but it apparently did not reach their growing points.

* The internode between the twelfth and thirteenth nodes was the same length as the one below, viz. eight inches.

Several instances of a similar nature, in which isolated masses of mycelium are found in the neighbourhood of only one or a few nodes of a bine, have been met with.

As regards the terminal "spiked" growths, many of these have been examined internally and the case of one typical (female) bine may be quoted in detail. This was pulled from the hill on June 12th when it had become spiked and had ceased growth at a height of five feet eight inches. It bore sixteen nodes and a terminal bud. The lowest four nodes were without leaves or laterals, these probably having been stripped by the pullers, but at the fifth and up to the ninth both leaves and laterals were healthy. Above this there were no laterals. At the tenth node the leaves were healthy but at the eleventh, twelfth and thirteenth there was yellow mottling on the upper surface of the laminae; on the lower surface, near the junction of lamina and petiole, black masses of conidiophores were becoming apparent. At the fourteenth, fifteenth, and sixteenth nodes the leaves were smaller, mottled with yellow, but as yet no fungus was visible. All growth from the tenth node upwards constituted the "spike," the internodes of which were from a quarter to two and a quarter inches long, whereas those below that node were eight to ten inches long.

This bine was split from the base to the apical bud, and mycelium, accompanied by brown discoloration of the pith, was found continuous in nodes and internodes for a distance of fifteen inches, viz. from the apical bud to a point one and a half inches from the ninth node. At this node, and extending to the base, there was no mycelium, and the pith and cortex were white.

Sections cut in the infected part of the main bine (as well as in terminal "spikes" subsequently examined) showed hyphae particularly grouped in the region of the pith and where this was hollow masses of hyphae were found abutting on, or projecting into, the pith cavity. Such masses were approximately $300\mu \times 300\mu$.

In two cases papillate conidia and one or two conidiophores were seen amongst the wavy hyphae which were projecting into the central cavity of the pith. It was later discovered that the accumulations of hyphae were actually there in readiness for the production of oogonia, antheridia, and eventually of oospores, within the pith cavity. The first case in which mature oospores were found is described later. At certain places long hyphae, measuring up to 900μ, were observed growing into the cavity.

The above is an instance of what is of general occurrence, viz. the "spiked" bine is free from mycelium below the spike. On this account the advice was given (9) to growers to remove all

terminal "spikes" by cutting to a point at which the pith was white and to a node from which healthy laterals could be trained up in place of the main bine.

Variations from the typical example are sometimes found. Thus a bine with fourteen and a half inches of terminal "spike" obtained from a wild hop plant was four feet seven inches high, with twenty-two nodes; mycelium was found extending from the apical bud through sixteen internodes, to a point eleven inches from the junction with the rootstock, *i.e.* through a length of three feet eight inches. Occasionally it may be observed that a pair of leaves or laterals at a node which contains the mycelium may be free from attack; sections in such cases have shown that apparently the mycelium has failed to penetrate although it may be present in the stipules. On rare occasions one leaf at an infected node may be attacked by mycelium within petiole and lamina and bear black masses of conidiophores, whilst the other leaf at the same node may not be invaded and is healthy. In such cases, hyphae are plentiful in the pith of the node but are scarce or absent from the cortex on that side of the node at which the healthy petiole is inserted.

Infected stipules bearing conidiophores are of common occurrence wherever leaf infection is found. Where the leaves are still unfolded, as in the terminal bud, the stipules are sometimes covered with conidiophores before these appear on the leaves. In cases where lateral shoots are in the "spiked" condition, it may happen (as with a pair of leaves) that one of a pair at a node is quite healthy, having a thin stem and long internodes, whereas the other is invaded by hyphae and is stunted, having curled, infected leaves.

One notable example of a variation from the general appearance was in the case of a bine from a wild hop growing in the hedge and observed on June 14th. This bine terminated in a completely hypertrophied tip, nine inches long, with short rigid lateral branches of four nodes and having the leaves subtending the branches, suppressed or nearly so.

It sometimes happens that the tip of a bine may be in the "spiked" condition and yet may show no fungus fructifications on the exterior of stem or leaves. When such growths are split with a knife, brown discoloration of the pith or cortex is found and hyphae are present in these tissues. One such "spike," nineteen and three quarter inches (50 cm.) long, cut from the top of a bine, contained mycelium from just behind the growing point to a distance of fifteen and a quarter inches (39 cm.) down the bine, where, in the middle of an internode, the mycelium ceased and the pith was no longer discoloured. In the terminal bud itself, two millimetres long (fig. 3), hyphae were found 250μ from the

summit (apex) in the pith, and from the cortex they extended into both leaves and stipules.

Accumulations of hyphae, such as have already been described, were commonly met with in "spikes" the pith of which was hollow. They could even be distinguished with the naked eye when the stem of the "spike" had been split longitudinally. Although the pith is described as "hollow," several layers of pith cells are found within the vascular cylinder and these, being faintly coloured brown, tend to show up the mycelium which forms a white lining for the hollow pith. On June 14th, mature oospores were discovered. A terminal "spike" which had been kept in the laboratory for three days, when examined, was found to contain some hundreds of oospores in the pith—more especially in the pith cavity, where they appeared to have been produced on or by the accumulations of projecting hyphae. In some cases a clear oogonial wall was discernible and the diameter of this was 40μ–50μ. Mature oospores with thick colourless walls measured 36μ–40μ.

Many other cases of plentiful oospore production were found after this date in the pith of "spikes" freshly cut and not kept in the laboratory. Oospores have been found between seven and thirty inches from the tip of a "spike." In one instance they were found in a broken leaf petiole and in another at the base of a "spiked" lateral above its junction with the bine.

In no case could the nature of the antheridia be distinguished with certainty and attempts to induce germination of the oospores have not yet been successful.

The Hop Cone.

As described in former articles(7,8), damage of the greatest economic importance is caused by this fungus when it attacks the cones of the hop. During 1925 damage of this nature occurred not only in this country but also on the Continent. Cones which are in all stages of development, from four mm. ($\frac{5}{32}$ in.) to five cm. (two inches) in length, and of a healthy green colour are liable suddenly to be turned brown in the course of a day or two.

During 1925 the first damaged cones were noticed on August 17th and, as on all subsequent occasions, angular spots caused by external infection were plentiful on the small cordate leaves which are borne on the branches of the female inflorescence close to the cones.

Conidiophores were abundant on the brown "petals" on both surfaces, though on the ventral they were more matted. By scraping or by examining the whole "petal" in a drop of water under the microscope, oospores were found (first on September

3rd) to be of common occurrence together with hyphae which ramified through the tissues. From this it is evident that the brown "petals" of affected cones can serve as a means not only of perpetuation but also of distribution of the disease. Cones discoloured through any cause are usually left unpicked in commercial gardens, with the result that "petals" (which are easily detached when ripe) may be carried considerable distances on the wind.

In view of the discovery of oospores in the cones, commerce in dried hops must not be lost sight of when considering means of dispersal of the disease. It is possible, however, that the process of drying may render any oospores incapable of germination*.

Hop Sets.

The presence of mycelium within the basal "spikes" arising from the rootstock in spring having been determined, investigations were next made to ascertain whether the mycelium is capable of hibernating in the perennial underground portions of the hop plant.

The most convenient material for study was provided by young plants having "crowns" or rootstocks derived from cuttings ("cuts" or "sets") planted one or two years previously†. Cuts are planted in nursery beds during the winter or early spring. They are the swollen bases of bines of the previous summer's growth which have been cut from the parent rootstock. In the nursery bed, they form roots and above-ground stems during the following summer; in the succeeding winter they are known as "rooted sets" and may be used for planting out in the hop-garden. If, however, they are left undisturbed for a further season, the rootstock increases in size and the set is then known as a "stag."

During visits to gardens in 1925, nurseries had been observed in which the young plants were plentifully marked by the brown angular spots caused by external infection of the leaves. Nurseries were also known in which "spiked" growths had occurred amongst the tangled mass of normal thin bines, and from one such as this, sets were obtained on October 29th.

This is a usual time for the digging of "sets"; the leaves have fallen, and all above-ground stems have by then turned brown and dried up ("died back") and the "sets" may be regarded

* In the process of drying in this country, the temperature does not exceed 140° F. when the hops are still moist and 160° F. when they are dry. The average time required is 9–10 hours. Sulphur dioxide is also used.

† The rootstocks of older plants in a hop-garden are very large and very tough and owing to the processes of "dressing" to which they are subjected, it is often impossible to distinguish the different years' growths.

as in the dormant winter condition. Several varieties were being grown in this nursery and five of these were especially chosen as having been heavily marked by the angular spot form of the disease on the leaves and as having shown a few "spikes" here and there in the rows.

The grower kindly supplied twelve sets of one variety and six of each of the others; choice of the sets, when dug, was quite at random, this being left to the hop-foreman.

The sets were washed, and it was observed that buds, in readiness for the spring of 1926, were numerous. These were in all stages of development up to one inch long and one-eighth of an inch thick*. After drawings had been made in every case, the brown withered stems of the previous summer were split and examined but no mycelium or oospores recognisable as those of *Pseudoperonospora* were found. The sets were then split longitudinally with a sharp knife. In three of the varieties, none of the eighteen sets showed any internal discoloration of the pith, phloem or cortex of 1925 or 1924 growth and sections cut in each one indicated that no mycelium was present. Of another variety, only one of the six sets was discoloured internally, and by means of sections numerous hyphae were found in the cortex and phloem of that set but not in the other five. Heavy infection, accompanied by discoloration, was found in five of the twelve sets of the remaining variety. Thus, in six of thirty-six sets chosen at random, in early winter, the fungus was found and there is every reason to believe that such sets, infested with mycelium, may be the means of carrying the disease into any hop-gardens in which they are planted.

The first set examined had only a small fragment of the original 1924 "cut" attached and consisted therefore mainly of the swollen base of the 1925 growth. It was three and a half inches long, measuring from the dead base of the 1925 bine, and 0·6 inch in diameter. At the top were two buds—one inch, and three-quarters of an inch in length respectively—and others, somewhat smaller, were situated at various points. Mycelium was found thickly massed in the cortex, phloem and medullary rays of the main stem. It was present at the bases of the buds and reaching as far as the brown bud-scales but in no case were hyphae found penetrating a bud.

There were eight roots, some of which were over eight inches long and 0·3 inch in diameter and it was noticed that some were tinged with brown for a short distance from their junction with the set. A median longitudinal section of the set showed that

* Early production of buds underground is found in the case of normal healthy hops. In 1925, buds up to half an inch long were observed on October 19th.

the cortex and phloem on both sides were discoloured throughout. The presence of mycelium in all the pale brown areas was confirmed and hyphae were also found (wherever there was brown coloration) permeating the cortex of the roots over an extent of one inch to one and a half inches from the set.

The other five sets had each a considerable length of older tissue. Mycelium was found in one of these extending throughout three and a half inches of the 1924 growth but the base of the 1925 bine had died back instead of thickening and it was therefore impossible to trace the mycelium into this. In the second, mycelium was found in the base of one of the 1925 bines (where it was massed in proximity to several buds) but it was not found in the 1924 tissue. In the third, it was present not only in the swollen base of the 1925 bine, but also in the cortex and phloem of the original 1924 set and was traced over a distance of three inches. The fourth and fifth sets were not split with a knife but small wedges were removed by cutting through the outer corky layer. Samples of the tissue were thus secured from the entire length of the sets and mycelium was found infesting the older (1924) parts throughout a length of four inches and one and a half inches respectively. In only one branch of one of these sets were hyphae found in the base of the 1925 growth also.

By not causing any serious damage to these two sets in the course of their examination they were kept in a state fit for further growth and after having been sketched and the position of buds and of mycelium noted, they were planted for further observation at a time when the buds are rapidly elongating.

Five further cases of invasion of the roots by mycelium were met with; hyphae were traced as far as two inches into the roots, of which some were nineteen inches long and otherwise healthy. A dark, almost black, coloration was noticed on the outside of roots which proved to be infected. This marking covered only the extent of the worst infestation and was not more than one and a half inches long.

Some alteration in the consistency of the phloem takes place in the presence of the mycelium. When the set is cut, even with a sharp knife or razor, an infected phloem is found to be more spongy and tears instead of being readily cut. It would appear that the fibres are no longer held in place when the medullary rays are infested. Hyphae were observed only once in the cushion of tissue on which buds are formed and never at that time of year were they seen to have entered a bud.

Methods.

In following the course of the mycelium in the living plant, specially at a time of the year when it was unaccompanied by any form of fructification, reliance was placed upon its general characteristics and on certain circumstantial evidence.

The great size of the hyphae—both as regards breadth and length, their generally unseptate condition, their apparently vigorous growth with occasional formation of a definite group or flat plate, their intercellular habit and, lastly, their characteristic haustoria were the principal features relied upon.

Within the pith or cortex of the "spiked" growths and of the bines, the hyphae are readily distinguishable in hand sections without the use of stains, but in the dense young tissue of a terminal bud and especially in the tough fibrous tissue of one- or two-year-old "sets" they were found extremely difficult to differentiate.

By the use of Azo Blue stain for all sections, the mycelium and haustoria were made readily visible. A one per cent. solution was made slightly alkaline by the addition of caustic soda until the colour was decidedly red. Sections of fresh material were cut and transferred directly to a drop of the stain on a slide. Parts of the hop plant being presumably acid, some sections tended to restore the blue colour of the stain; to prevent this, a small glass rod, previously dipped into a weak solution of caustic soda, was, when necessary, brought into contact with the drop of stain and the red colour, which gave the best results, was again obtained.

Both the host tissues and the hyphae became stained, but the latter more deeply than the former. Haustoria were specially well defined. Where the hyphae were few or did not readily stain, the sections were left for one or two hours in the stain on the slide; as a rule, however, staining was immediate.

Conclusions.

The principal fact brought to light by the investigations of 1925 is that mycelium of the fungus may persist during the winter in underground portions of the hop plant. Similar behaviour by species in four genera of the Peronosporaceae has been recorded between 1861 and 1915 by various authorities, and their observations have been summarised in a paper by Melhus(4), who has himself contributed five such records.

Since that date, further examples or confirmation of the existence of a perennial mycelium in the Peronosporaceae have been provided; in 1920 by Gardner(2) in the case of *Peronospora parasitica* in turnips; in 1921 by Murphy(5) in *Peronospora*

Schleideni in onions and shallots; and in 1925 by Klebahn(3) in the case of *Peronospora pulveracea* in *Helleborus* sp.

In the present fungus, it has not yet been possible to connect the mycelium found in the underground parts, with the fruiting stage either by pure culture or by exposing the cut surface of "sets" to a damp atmosphere. There can be little doubt, however, that the Downy Mildew does indeed over-winter in the rootstock and the inference is that in early spring it probably invades one or more of the developing buds, apparently either overwhelming the young shoot—in which case a basal "spike" would result—or is carried by the rapidly elongating bine close behind the growing point. In the latter case it would appear from the sections made that the mycelium may either be carried up to a considerable height in its entirety or small quantities may be deposited at certain nodes in the course of the rapid upward growth of the bine. This procedure, if it takes place, would account for the formation of diseased laterals at isolated nodes and of terminal spikes at any height from the ground.

It must be pointed out, however, that up to the present the actual passage of the mycelium from the rootstock into an elongating bud has not been observed.

Whether "spiked" growths may be caused by external infection, an alternative suggestion put forward in an earlier paper(8), still remains to be proved. Professor Ducomet(1), in an account of his observation of the disease in France, is of the opinion that early external infection alone takes place and that this is sufficient to account for all the forms of "spiked" growths.

The above work has been carried out in co-operation with Professor E. S. Salmon, with whom visits were paid to numerous hop-gardens where the necessary material was obtained. The author desires to express his thanks for these and other facilities.

Summary.

An account is given of the discovery and investigation of an internal invasion of the Hop (*Humulus lupulus*) by the Downy Mildew *Pseudoperonospora Humuli* (Miyabe et Takahashi) Wils.

Hyphae are present within the cortex and pith of the stem of "spiked" growths from the rootstock and are also present in one-year-old parts of the rootstock. In the case of longer bines with terminal or lateral spikes, the mycelium is found within the bine but is not necessarily continuous and healthy intermediate nodes and internodes may occur. Mycelium has not been observed at the base of such longer bines.

The fungus is present in the winter in the pith, phloem and cortex of nursery "sets" and in several cases has been found in the cortex of the roots.

Oospores occur plentifully in the pith of terminal and lateral "spikes" and within the bracts and bracteoles of the "cone."

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EXPLANATION OF FIGURES 1–4.

Fig. 1. Downy Mildew of the Hop: Portion of a rootstock showing one healthy and two diseased shoots in the form of basal "spikes," with small, curled, grey-green leaves. In the "spikes," mycelium was present, and in this case was traced only as far as the junction with the rootstock. The healthy shoot (left) is distinguished by its longer internodes, sinuous growth, and normally expanding dark green leaves. April 27th, 1925. Natural size.

Fig. 2. A nursery set (in section) derived from a cutting planted in 1923, and examined November 11th, 1925. Mycelium of *Pseudoperonospora Humuli*, the position of which is diagrammatically represented in red, was found in the bast and cortex of the older parts and also in the swollen base of the 1925 growth. In addition it was present in the roots. 0·8 Natural size.

Fig. 3. Diagrammatic outline drawing of a freehand section cut longitudinally through the apical bud of a bine with terminal "spike" at about seven feet from the ground. The position of mycelium is represented in red. From here, hyphae were traced downwards to a distance of 39 cm. in the bine. ×28.

Fig. 4. Section passing through a bud on the older portion of the set shown in fig. 2. Examination of sets in winter (November) indicated that buds were not invaded by the fungus. Position of mycelium shown in red. 0·8 Natural size.

HETEROTHALLISM IN THE GENUS PENICILLIUM.

A PRELIMINARY NOTE.

By Dr H. G. Derx.

THE occurrence of ascocarps in the genus *Penicillium* is rather uncommon, reproduction taking place as a rule by means of abundant conidia. In some cases, however, ascocarps have been found and described more or less adequately, but it is usually impossible to corroborate investigations of older authors, either because their strains are no longer obtainable, or because it would seem that some species of *Penicillium* lose the faculty of producing asci after a certain number of transplantings on artificial media.

A study of the different perithecia described in this genus leads to the conclusion that they differ to such an extent that it would seem impossible to unite all species in one genus. Some species form perithecia resembling those of the genus *Gymnoascus*; others should be placed in the genus *Eurotium*; and yet others seem to form asci in the interior of sclerotia after a resting period which may be considerable.

So far I have never seen perithecia formed in the last two ways; sclerotia sometimes appeared but asci never developed in them. I have, however, in pure culture four species of *Penicillium* the perithecia of which closely resemble those of *Gymnoascus*, with the only difference that the enveloping hyphae of the ascocarp are more closely interwoven than is usual in that genus.

These ascocarps are formed with great regularity and, in certain circumstances, so abundantly as to crowd out the conidial form almost completely.

At present I have the following species in culture:

1. *Penicillium Wortmanni* Klöcker (1903), kindly sent to me by Professor Ph. Biourge, who obtained it from Klöcker.

2. *Penicillium vermiculatum* Dangeard (1907). This curious species was described in detail by Dangeard, but has escaped the attention of specialists. Besides a strain isolated by myself I possess that described by Thom as *Penicillium luteum* (Washington, No. 11), which is identical with this species.

3. *Penicillium luteum* A. Richards (1924). The name of this must be changed. It is quite different from *Penicillium luteum* Zukal (1893) and from *P. luteum* Thom mentioned above. I obtained it from the Centraalbureau voor Schimmelcultures at Baarn (Holland).

4. *Penicillium luteum* (Zukal?) Wehmer *certissime*. This is the species in which I discovered heterothallism. It is the only *Penicillium* in my collection which agrees in all points with C. Wehmer's description of *Penicillium luteum* Zukal.

I am very much obliged to Dr Ch. Thom for sending me five other strains of ascogenous Penicillia, which with those mentioned above will form the subject of a further communication in which their characters and especially the development of perithecia, etc., will be described in detail. I hope that other workers will kindly send me any ascogenous Penicillia they might possess or isolate as it is only by such aid that a more or less complete knowledge of the ascocarps in the genus *Penicillium* can be reached.

Numerous different species have been named *Penicillium luteum*. Almost every mycologist has a *Penicillium* of this name in his collection, but few investigators have ever seen the typically formed ascospores as figured by Zukal. Yet many authors, when describing their *Penicillium luteum*, content themselves with referring to Zukal for a description of ascocarps.

According to Zukal the asci are formed in perithecia consisting of closely interwoven hyphae, which are at first yellow, then orange, and which at last turn blood-red.

The asci are stalked; the ascospores are oval, $4{\cdot}8\mu$–$3{\cdot}3\mu$ with four verruculose, tricostate ridges. The conidiophores typically produce a verticil of metulae, each of which is crowned by a verticil of conidiiferous cells. The conidia are blueish-grey.

The only author who described ascospores which could be mistaken for those of Zukal's *Penicillium luteum* is Wehmer, who in 1893 described a mould which he stated was extremely common, and which he considered identical with *Penicillium luteum* Zukal. The ascospores of Wehmer's mould certainly have three or four cross-ridges, which are however perfectly smooth, instead of being verruculose. One might possibly attribute Zukal's account of wart-like prominences on the extremely fine ridges to optical illusion due to imperfection of the microscopes in his day, but this suggestion remains to be proved.

I therefore believe that the mould which I found to be heterothallous, and which presents all particularities described by Wehmer, should be named provisionally: *Penicillium luteum* (Zukal?) Wehm.

The orange-red perithecia of this mould were found growing on the sand of a dried-up aquarium and contained ascospores closely resembling those drawn by Wehmer. The perithecia were crushed and planted on cherry-juice agar. A *Penicillium* developed, which produced, besides abundant perithecia, the biverticillate conidiophores as described by Wehmer. These

characters repeated themselves in subsequent transfers on the same medium, but the quantity of perithecia produced diminished constantly, and with fear I foresaw the moment, that—in close accordance with the experiences of Wehmer—they would no longer be produced at all.

I tried to purify the original culture by the dilution method in Petri dishes. Several strains were isolated, which, though morphologically identical, presented some differences in physiological characters. Some strains, on Raulin-Dierckx gelatin at 20° C., produced dark olive-green conidia; the reverse of their colonies was of a brilliant orange colour, which did not diffuse into the gelatin. The medium was liquefied after some days, and large quantities of minute crystals (calcium oxalate) were formed, which clouded the liquefied gelatin. Other strains, on the same medium, produced blueish grey-green conidia, the reverse, instead of being dark orange, only showing patches of a currant-red, diffusable colour. Gelatin was liquefied slowly, without clouding, but finally becoming deep red in colour.

None of the strains thus isolated ever produced perithecia, whereas, on the other hand, ascocarps were formed after some weeks in the original Petri dishes.

Thus there remained only one way to obtain the ascogenous *Penicillium* with certainty, *i.e.* to make single ascospore cultures.

With the aid of the apparatus of Janse and Péterfi I succeeded in obtaining twelve such strains, each grown from a single ascospore. They were identical with the strains isolated by the dilution method, and showed the same physiological differences. But not one perithecium was formed. At the most yellow mycelial masses, closely resembling perithecia, were formed in some strains, but these masses were quite devoid of asci. It is now clear to me that these empty masses are "haploid ascocarps" comparable to the haploid fructifications of *Coprinus fimetarius* described by Brunswik.

These mono-ascospore cultures, however, readily and abundantly produce well-developed ascocarps when they are grown two by two in certain combinations. When this point had been fixed, the different strains isolated from conidia behaved in the same way.

Thus, the heterothallism of *Penicillium luteum* (Zukal?) Wehm. is beyond doubt.

Table I shows the result of the crossing experiments of the twelve mono-ascospore cultures in all possible combinations. It will be clear that the strains may be divided in two groups. There are (+) strains: *B*, *C*, *H*, *I*, *L*, *M*; and (−) strains: *A*, *D*, *E*, *F*, *G*, *K*. It goes without saying, that the choice of the signs (+) and (−) for either group is at present absolutely

arbitrary; only a cytological examination would enable one to decide whether a certain sign is proper to one group rather than to the other.

Table I.

Mono-ascospore strain	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*K*	*L*	*M*
A	—	1	1	—	—	—	—	2	1	—	2	1
B	1	—	—	2	3	3	1	—	—	1	—	—
C	1	—	—	2	3	3	1	—	—	1	—	—
D	—	2	2	—	—	—	—	3	2	—	3	2
E	—	3	3	—	—	—	—	4	3	—	4	3
F	—	3	3	—	—	—	—	4	3	—	4	3
G	—	1	1	—	—	—	—	2	1	—	2	1
H	2	—	—	3	4	4	2	—	—	2	—	—
I	1	—	—	2	3	3	1	—	—	1	—	—
K	—	1	1	—	—	—	—	2	1	—	2	1
L	2	—	—	3	4	4	2	—	—	2	—	—
M	1	—	—	2	3	3	1	—	—	1	—	—

The numbers indicate the relative quantity of perithecia developed:
— = none. 1 = very feeble. 2 = feeble. 3 = good. 4 = abundant.
The strains *E*, *F*, *H* and *L* show sterile, haploid ascocarps.

Table I also shows that in both groups one may remark distinct differences in sexual activity. For instance, the strains *A* and *G* only form perithecia abundantly with the strains *H* and *L*. Thus the strains *H* and *L* show the greatest sexual polarity of the (+) sign. They are more active than the strains *B*, *C*, *I*, and *M*. Among the (−) strains, the cultures *E* and *F* possess the largest degree of sexual polarity. The strains *A*, *G* and *K* are only feebly "polarized." Further, the strains of great sexual polarity in *both sexes* are capable of forming *sterile* haploid ascocarps without being crossed.

In this connection it is very interesting to remark that there would seem to exist some parallelism between the degree of sexual polarity and some purely physiological characters. The strains quickly liquefying gelatin and of which the reverse on Raulin-Dierckx gelatin is deep orange are among the most active in their sexual reaction (*B*, *C*, *E*, *F*, *H*, *L*). The strains *A*, *D*, *G*, *I* and *K* liquefy gelatin only slowly, with production of the red diffusable colour; their sexual activity is at the same time rather feeble.

The question arises whether the sexual activity remains constant after several transplantings. It will be equally interesting to establish whether it appears unchanged in the F_1 generation. Also the problem must be solved, whether the physiological differences of the strains are due to true mutations or whether they are merely degenerative modifications (mutilations!).

Cytological researches must first be made to elucidate the manner in which the sexually different thalli fuse, the way in which gametophores and ascogonia are formed, and the cytological phenomena of fusion and ascus formation.

Penicillium luteum (Zukal?) Wehm. furnishes the first example of heterothallism in this common genus.

Certainly it will not remain unique for long. In fact most of the strains available in collections are the result of repeated purification by the dilution method, so that there is some chance that they are derived from single conidia. Others have been found more or less accidentally in air-dust. Modern methods of purification have certainly contributed to the relative rarity of ascocarps observed recently, so that it would be of some interest to cross strains of the same, or of morphologically similar moulds occurring in different collections.

I wish to express my thanks to Professor Dr A. J. Kluyver for the hospitality I have enjoyed in the Laboratory of Microbiology of the Technical University at Delft and to Mr C. B. van Niel, curator of this laboratory, for his kind and indispensable aid in the isolation of single ascospores with the apparatus of Janse and Péterfi.

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ON THE OCCURRENCES OF A SPECIES OF COLLETOTRICHUM.

By W. Small, M.B.E., M.A., B.Sc., Ph.D., F.L.S.

Introduction.

It has been the experience of the writer to find in the course of his general mycological work in Uganda that forms of the genus *Colletotrichum* obtrude themselves upon his notice more frequently, perhaps, than forms of other equally widely distributed tropical plant-inhabiting fungi, and, in any case, so frequently that they compel a certain amount of attention. It is the purpose of this paper to relate some of the occurrences of a species of the genus and the experimental work conducted with the various isolations of the species in question. The study was

undertaken in order to establish or, at least, throw light upon the local status of the various forms encountered and the nature of the species which can be found on so much diverse material. In passing, the writer wishes to make a plea for similar studies of similar fungi occurring in other parts of the tropics. By "similar fungi" is meant such forms as occur on many different substrata, have among themselves a strong morphological likeness but a less well-marked habit of parasitism or saprophytism, and occur in a definite restricted area. The accumulated data from such work would be of great and increasing importance as their significance was gradually extended beyond their original local limits by the linking up and correlation of results and conclusions.

The writer has been accustomed to refer to the species of *Colletotrichum* which forms the subject of these notes as *C. coffeanum* Noack. Since other specific names of *Colletotrichum* are as applicable as *coffeanum* on morphological grounds, and one of them at least, *incarnatum*, was described by Zimmermann from cacao pods in the same year (1901) as *coffeanum*, and another, *Camelliae*, was instituted by Massee as early as 1899, *coffeanum* was adopted not for reasons of priority. It was, however, the name given to the first *Colletotrichum* encountered by the writer in Uganda, and, as it then occurred on *Coffea arabica*, it was natural to refer to it as *C. coffeanum* and to apply the same name to forms which, although they occurred on host plants other than coffee, were morphologically indistinguishable from the original *C. coffeanum*. The name *coffeanum* has thus been retained primarily for reasons of convenience, and, since it has been shown that many of the forms labelled *coffeanum* in these notes are characterised by the perfect stage *Glomerella cingulata* (Stonem.) Spauld. and v. Schr., and that that name should therefore be used in reference to them, the actual designation of the conidial stage is a matter of minor importance. In describing the species from leaves and twigs of coffee in Brazil, Noack gave the conidial measurements as 12–18 × 4–5μ and the diameter of the acervuli as varying from ·15 to ·18 mm. The pink or flesh-coloured masses of conidia are distinctive, and *coffeanum*, as it is found on coffee in Uganda, either causing what is known as brown blight of leaves and berries or living saprophytically on dead or dying branches, corresponds in the main to these measurements. Noack gave no measurements of the setae often present on the acervuli of *C. coffeanum*, but Butler's "four or five times as long as the spores" is sufficiently accurate for practical purposes*, although setae up to 180μ in length have been found on material kept in the laboratory. The

* Fungi and disease in plants, 1918, p. 482.

presence or absence of setae is well known to be a variable character in *Colletotrichum*, and it is now generally recognised that the genus *Gloeosporium* is, at least in part, only a *Colletotrichum* without setae. No distinction is made here between the two genera, and the generic name *Gloeosporium* is not used, although it is in many cases as applicable as *Colletotrichum*. In the various occurrences of *C. coffeanum* listed below, the most constant morphological features of the species are the conidial sizes, the pink coloration of the conidial masses and the dimensions of the acervuli, and, on these features alone, the placing of the different forms in *C. coffeanum* is justified. Less rigid morphological characters are the presence or absence of setae and the presence or absence of the ascomycetous or *Glomerella* stage of the fungus. Setae are most commonly present on a dry or drying substratum both in nature and in artificial culture, and, while their presence or absence has thus been found to be in part a response to environmental conditions, it cannot be said that such conditions are entirely responsible for their development or non-development or that they can be produced or suppressed at will. At the same time, observations on several generations of different isolations of the fungus grown on half-a-dozen different media have not shown that any of the strains possesses an innate or heritable tendency towards setal production, and the development of setae would therefore seem to be controlled by arbitrary or even accidental factors. In the case of the perfect stage of the *Colletotrichum*, the production of perithecia under laboratory conditions has not been proved to depend on the substratum, whether natural or artificial, and it seems as if the opinion expressed by Dastur*, that the perithecial-forming faculty is the outcome of some quality inherent in the strain of the fungus, holds in Uganda.

The Hosts of *Colletotrichum coffeanum*.

The following list of occurrences of *C. coffeanum* in Uganda is representative but by no means exhaustive. Notes on each case are appended, and it will be observed that the fungus is at times apparently parasitic and at others palpably saprophytic. On the whole, my impression is that the tendency of the *Colletotrichum* under discussion towards saprophytism or weak parasitism is stronger than its leaning towards obligate parasitism. *Colletotrichum coffeanum* has been under observation in the field for more than ten years and there is no evidence of an increasing amount of growth on the part of the fungus on, for example, coffee, a plant which it has had unlimited opportuni-

* Ann. Appd. Biol. VI (1920), 245.

ties of attacking. Among the plant diseases caused by *C. coffeanum* in Uganda, none approaches in virulence the diseases of citrus caused in Florida by *C. gloeosporioides* (Penz.) Sacc., the anthracnose of cotton caused by *C. Gossypii* Southw. in the United States of America, or the anthracnose of beans due to *C. Lindemuthianum* Br. and Cav., despite the fact that these species of *Colletotrichum* are of the same morphological type as *C. coffeanum*. It was stated by Noack himself with regard to *C. coffeanum* in Brazil that the fungus did harm only to weakly trees, and there is much field evidence in Uganda in favour of the view that, other things being equal, the healthy plant has less chance of being attacked by *Colletotrichum* than its sickly or overburdened neighbour.

Identification of the fungus is based upon the more constant morphological details mentioned above, for they, as criteria, must assume a greater importance than usual in the case of a species which not only occurs on many different substrata but also has no definite and constant habit of growth. Also, the identification of the *Colletotrichum* on the various natural subtrata has been supported in every case by cultural comparisons so that there might be no doubt of the accuracy of the naming. It has been shown by various writers, and more recently by Dastur* and Burger†, that variations within species of the genus *Colletotrichum* take place in culture, and it has been found that, apart from the question of the identity of the species studied by these authors with the species *C. coffeanum*, similar variations occur in Uganda. Purely morphological studies, however, have been subordinated to the physiological side of the work on *C. coffeanum*, and, while they are reported in these notes, they have not been pursued as fully as their importance warrants. More time and attention have been given to the inoculation and cross-inoculation studies which are discussed later.

1. *Coffee.* Brown blight of coffee (*C. arabica*) leaves and berries has been known in Uganda since the beginning of *arabica* cultivation on a large scale about fifteen years ago, and *C. coffeanum* has been proved to be the cause of it. The same fungus occurs on the branches of trees in the desiccated condition known locally as "dieback," but it has been shown to have little or nothing to do with bringing about this which is really due to mal-nutrition caused by a complex of physical and physiological factors‡. It follows also in the wake of certain sucking

* Loc. cit.

† Jour. Agric. Res. xx (1921), 723.

‡ Circs. Nos. 4 and 9, Dept. of Agric. Uganda, 1920 and 1923; Kew Bulletin, 1921, p. 57.

insect pests that kill back young shoots, for example, the capsid bug *Lycidocorus mimeticus* R. and P. In fact, the conidia of *C. coffeanum* are so commonly present on coffee in the field that a large proportion of healthy green twigs and leaves plucked at random and placed in a damp chamber for a few days without surface-sterilisation will yield acervuli of *C. coffeanum* on both wood and leaves, and it follows that, if *C. coffeanum* were a consistently aggressive parasite of coffee, the results of its presence would be disastrous. On the contrary, brown blight is not a very common trouble, and it has never assumed the proportions of an epidemic. The same *Colletotrichum* occurs on *robusta* leaves, berries and twigs in circumstances similar to those under which it is found on *arabica*, and it has been noted in association with *Cephaleuros Mycoidea* Karst. on twigs, leaves and berries of *liberica* coffee. The fungus may therefore be found on coffee as a parasite or as a saprophyte. The perfect stage has been obtained on *arabica* twigs and in culture from several strains and has been identified as *Glomerella cingulata*.

2. *Cacao.* A *Colletotrichum* indistinguishable morphologically from the form on coffee has been obtained on several occasions from rotted and hardened cacao pods and from apical twigs which had died back. Certain strains of the cacao fungus were tested in 1919–20 and found to be only wound parasites of cacao. The same strains, however, infected coffee leaves. They developed the same *Glomerella* stage as the coffee strains, and could therefore be safely named *C. coffeanum**.

3. *Cotton. C. coffeanum* is frequently found on bolls in association with a discoloration which resembles the anthracnose caused in other regions by *C. Gossypii* Southw. No doubt true anthracnose is present in Uganda, but a boll discoloration which is not true anthracnose is quite common. It is probably caused by the sucking of insects, and the fungus associated with it may therefore be a saprophytic follower of injury brought about by another agent. Attempts to induce the fungus, recently isolated from a discoloured boll, to penetrate the unbroken skin of a healthy boll have failed, but when the fungus is provided with a passage through the skin of the boll in the form of needle-prick wounds it is able to live on the boll tissue and contents and cause or initiate a kind of internal rot.

An anthracnose of cotton seedlings which agreed in its symptoms with a similar trouble in the United States of America† was found for the first time in Uganda in 1924. Many of the affected plants recovered from the disease, but they did not make full normal growth and they bore a reduced number

* Kew Bulletin, loc. cit.

† Farmers' Bull. 1187 (March, 1921), 15, fig. 10.

of bolls at maturity. The only fungus isolated from the diseased tissue was *C. coffeanum.* Inoculation experiments were attempted by three methods. In the first, cotton seedlings and the *Colletotrichum* were grown together in large tubes in dilute Richards' solution, but, as the medium could not be kept free of contaminations and the control plants did not thrive, the results were invalidated. In the second, cotton seedlings were grown in tins of sterilised soil into which, among the roots of the plants, large numbers of viable conidia in sterile water and in sterile weak cane-sugar solution were injected by means of a small syringe. Both control and inoculated plants grew normally, and results were therefore entirely negative. It should be added that the seeds used in the foregoing experiments were delinted with sulphuric acid and surface-sterilised before germination. In the third method, both delinted and sterilised and untreated fuzzy seeds were used. Inoculation was attempted by dipping the seeds in water containing conidia and immediately planting them, by a similar dipping followed by an incubation period of forty-eight hours in a damp chamber before planting, and by placing drops of water containing conidia on needle-prick wounds, a process which was followed by incubation for forty-eight hours before planting. The first two sets of these latter experiments gave negative results with both delinted and fuzzy seed, and the third lot gave positive results only in the case of the delinted seed. The resulting anthracnose, however, was more severe than the field disease, for it attacked eighty per cent. of the plants and proved fatal to more than half of them. The results point to the necessity for the presence of the fungus (at least of the strain employed) within the seed as a preliminary to the causation of seedling anthracnose, and they also disclose the possibility of the passing of the *Colletotrichum* from an apparently saprophytic condition on a boll to a parasitic state on young seedlings viâ the seed, a point of practical (and theoretical) importance which the writer hopes to investigate more fully during the next cotton season.

4. *Beans.* An anthracnose of the pods of French or kidney beans (*Phaseolus vulgaris* L.), the symptoms of which are identical with those described from other areas, occurs at times, and the *Colletotrichum* associated with the disease is indistinguishable from *coffeanum.* It has been proved to be capable of causing the anthracnose of pods. The *Glomerella* stage of the fungus has not been obtained, nor has the affection caused by the *Colletotrichum* been found on any part of the plant but the pods. In 1924, *C. coffeanum* occurred on the stems of a small proportion of a number of native beans (*Phaseolus* sp.) which had been wilted by an attack of *Sclerotium bataticola* Taub. during

a spell of hot dry weather, but it was shown to be an inactive agent in the production of the wilt through the soil*. The *Glomerella cingulata* stage of this strain was found in old dried cultures.

5. *Tea. C. coffeanum* has been found upon the leaves, twigs and seed-vessels of tea plants grown for seed purposes. The leaf blotch which it causes resembles the brown blight of coffee, and it is often caused by the *Colletotrichum* alone; that is to say, unaccompanied by other fungi like *Pestalozzia*. The extent to which the fungus is responsible for injury to branches or seed-vessels has not been determined, but a recent isolation from leaf-blotch has been proved to be able to blight a small proportion of the leaves of young plants when brought into contact with their upper surfaces. The relation of the fungus to the tea plant is probably of the same nature as it is to coffee, and its perithecial stage is *Glomerella cingulata*.

6. *Citrus. C. coffeanum* has been encountered on orange leaves, where it has an effect similar to that on coffee and tea leaves. A few upper-surface inoculations on the leaves of young orange plants have been successful in producing a browning resembling that which occurs in nature, but infection is slow. The period required to produce the leaf blight is three or more weeks.

7. *Chillies.* A ripe rot of the fruit of a local *Capsicum* (probably *frutescens* L.) is caused by *C. coffeanum*. The fungus has been recorded only on the ripest fruits, and it has not been noted to cause an anthracnose as distinct from a ripe rot. The trouble, however, is not common.

8. *Hevea brasiliensis* Müll.-Arg. The fungus has been found on leaves and small dieback twigs of the Pará rubber tree. It has not been seen on the fruits. While it may cause defoliation on a small scale, as on young plants in laboratory experiments, there is no evidence that it does so on a large scale in the field. Its presence on twigs is probably a danger inasmuch as it may lead to attacks of the dieback fungus *Botryodiplodia Theobromae* Pat.

9. *Mango. C. coffeanum* causes an anthracnose or spotting and a ripe rot of mango fruits. Both affections have been reproduced under laboratory conditions, but, in recent work, a ripe-rot strain of the fungus could not be induced to penetrate the unbroken skin of green unripe fruit. It is not known with certainty whether the fungus also causes an anthracnose of floral branches and whether it infects the fruits in their younger stages. *C. coffeanum* was obtained several years ago from the floral branches of a tree which failed to set its fruit, but its con-

* Kew Bulletin, 1925, p. 118.

nection with the trouble was not proved. *Glomerella cingulata* has been developed on pieces of skin removed from successfully inoculated fruits and kept in a dry place under cover.

10. *Avocado pear* (*Persea gratissima* Gaertn. f.). Black spots are common on the fruits of avocado, and *C. coffeanum* can be isolated from the diseased tissue. The fungus is also associated with a ripe rot of the fruit. Black spot has been reproduced only through needle-prick wounds, a result that agrees with the finding of Stevens in Florida*. *C. coffeanum* has been found at times also on small branches which have dried up, but it was not shown to cause a dieback in a series of tests in 1922. *Glomerella cingulata* has also been obtained on or near the sites of old *C. coffeanum* acervuli on the branches.

11. *Soursop* (*Anona muricata* L.). *C. coffeanum* has been isolated from dieback twigs and spotted fruits of the soursop, but no experimental work has been carried out with this host.

12. *Papaw* (*Carica Papaya* L.). An anthracnose of flowers and young fruits such as is described by Dastur† has not been recorded in Uganda, but *C. coffeanum* has been found several times in association with darkened depressed areas of fruits which are about to change colour and ripen. The affection of such fruits spreads until it becomes a general rot. A recent strain of the fungus isolated from a depressed area of a green fruit was found to be capable of reproducing the affection on unripe fruits only when introduced through needle-prick wounds after the milky flow from the punctured skin had ceased and had been cleared away; it was proved to be incapable of penetrating the skin of even over-ripe fruits. It is therefore possible that infection takes place through the flowers or, at least, at an early stage of fruit development, but it is also possible that the *Colletotrichum* is introduced into the older papaw fruit by a sucking insect. If infection took place through the flowers, the fungus might be found in the fruit stalk, but it has been detected in that position only once, and it may have attained it then by external accidental means. The *Glomerella cingulata* stage of the fruit strain has been obtained in culture.

13. *Vanilla*. *C. coffeanum* has been isolated from diseased areas of vanilla leaves and from a flower bud that refused to open in a normal manner, became brown in colour, and finally dropped off the plant. On the leaves, the fungus is associated with sunken grey spots which are often edged with a narrow band of dark tissue and which in time become "shot-holes"; it is accompanied at times by a species of *Fusarium* and by saprophytic forms. Two isolations of the leaf-spot *Colletotrichum* have been tested on vanilla leaves and have been found unable

* Rev. Appd. Mycol. 1 (1922), 432. † Loc. cit. 264.

to penetrate the unbroken skin or to enter into and live upon the leaf tissue even when this is wounded by needle-pricks, while the *Colletotrichum* isolated from the flower bud has not been shown to affect flower development in the few experiments attempted. The soft rot of vanilla ascribed to a *Colletotrichum* in Ceylon* is not known in Uganda; indeed, the local troubles of vanilla are severely restricted, and the writer is of opinion that they may be primarily due to insect attacks.

14. *Bananas, figs and fruits of Voacanga Thouarsii* Roem. and Schlt. *C. coffeanum* is responsible for ripe rots of these fruits. There are large numbers of banana plants in parts of Uganda, but ripe rot of the fruit is remarkably uncommon and green fruit has never been found to be attacked. More tests have been made with bananas than with the other two fruits, but it seems that, in all three cases, *C. coffeanum* is unable to penetrate the unbroken skin of sound fruits. The fungus has not been found on any other parts of the respective plants. *Glomerella cingulata* has been obtained in fig and *Voacanga* cultures.

15. *Oil-palm.* The pink spore-pustules of *C. coffeanum* can often be found on the husks of ripe seeds of *Elaeis guineensis* Jacq. in the company of *Botryodiplodia Theobromae* Pat. and species of *Fusarium* and *Pestalozzia*. The fungi are confined to the outer fibrous part of the husk of the fruit, and the inner harder husk and kernel are unaffected. The harm done by any or by all of these fungi might presumably be of account in the extraction of oil from the pericarp, but it is not known how far they are responsible for deterioration of the husk. There is no local oil-palm industry of importance, and no experimental work on the tree or its products has been done. It is probable that the nut fungi are present only as ripe-rot forms and that they could be avoided by an early gathering of the fruit.

16. *Native raspberries. C. coffeanum* has been found on native raspberries in association with *Cladosporium herbarum* Lk. The parts played by the respective fungi have not been determined, but it was noted that the result of their attack was a complete rot of the fruit pulp.

17. *Ground-nut leaves. C. coffeanum* has been isolated from dead discoloured areas of ground-nut leaves. The fungus, however, was shown to be unable to reproduce the leaf spots, and, further, it is likely that the spotting was associated with a kind of rosette disease which may be shown to be due to an aphis. This strain developed perithecia of *Glomerella cingulata* on potato plugs in Roux tubes in five weeks.

* Year Book, Dept. of Agric. (1924), 52.

Morphological Notes.

Considered apart from the question of the comparative susceptibility of the host plants, the above occurrences of *C. coffeanum* can be divided into three physiological groups, the apparently parasitic, the weakly parasitic capable of initiating ripe rots or requiring a wound entrance to host tissue, and the apparently saprophytic. The possibility of the existence of morphological features which might be distinctive of the physiological character of any particular strain of the fungus has always been kept in mind, but, on the whole, the natural morphology of *C. coffeanum* has been found to be very constant. Slight variations, however, in the colour of the pustules of conidia and in the sizes of the spores occur at times. For example, the pustules of bean anthracnose may be of a yellow tint and those of the brown blight of *robusta* coffee leaves may be almost dark grey instead of the normal pink or flesh colour. These differences of colour seem to be due partly to the substratum and partly to conditions of moisture, and they are not accompanied of necessity by differences in conidial sizes or by the presence or absence of setae, and so on. Again, when the fungus is induced to fruit *in vitro*, the conidia occasionally exceed the normal size. Thus, conidia from the fungus on discoloured cotton bolls have measured as much as $25 \times 6\mu$, and conidia from a diseased vanilla flower bud have appeared to be of two types when young, the first long and narrow and measuring $22{\cdot}5 \times 5\mu$ and the second shorter and broader and measuring $15 \times 7\mu$. Such abnormal conidia are formed only under conditions of excessive moisture, and they are not uncommon. Moreover, they are accompanied and succeeded by conidia of average size, and they give rise to normal growths of the fungus in artificial culture. The average size of conidia developed in the laboratory is $15–20 \times 4–5\mu$, a measurement which exceeds the figures given by Noack but which is constant in, and typical of, all the strains of *C. coffeanum.*

All the strains listed above have been grown in pure culture at one time or another, but the following notes refer particularly to recent studies of strains of *C. coffeanum* isolated from brown blight of *arabica* coffee leaves and of berries, from brown blight of *robusta* coffee leaves and of berries, from a healthy *robusta* twig after damp-chamber treatment, from brown blights of tea and orange leaves, from an orange twig, from the discoloured skin of a cotton boll, from cotton seedling anthracnose, from anthracnose of French beans, from mango ripe rot, from discoloured papaw fruit, from a diseased vanilla flower bud and from dead parts of ground-nut leaves. These strains of *C. coffeanum*

have been grown upon potato plugs in Roux tubes and on Dox, Lima bean, potato, malt extract, prune and maize-meal agars. Aerial mycelium develops in culture in two prominent ways. In one type of growth, it is large in amount and at first white in colour. Its texture is cottony or fluffy, and it covers the whole surface of the slant in a tube culture. It becomes black in contact with glass, and the white colour may persist or become dirty-white, or even greyish. In the other, it is small in amount, white or dirty-white in colour, sometimes becoming grey or black, and it is powdery in texture. In both cases pustules of conidia develop rapidly and in great numbers. In the first type the pustules may be masked by the mycelium, to which they may give a pink tinge; in the second, their presence is more apparent. At times, the pink masses of conidia may cover the whole slant and give it an oily appearance. These types of development in culture are more frequent than others, and they are regarded as typical of *C. coffeanum.* Most frequently both types appear in different cultures of all the strains, and while it seems that certain media, for example, Dox agar, tend to induce the formation of a large aerial mycelium, and others, for example, Lima bean and potato agars, tend to produce a powdery aerial growth, it can be shown that they do not do so with regularity and that either type of aerial growth may appear on any of the media. Certain strains, however, like those from mango ripe rot and vanilla flower bud, have shown a greater tendency than the others towards the smaller aerial mycelium. It has also been noted that the larger aerial growth is associated with a smaller number of conidial pustules and with a tendency to bear conidia directly upon the hyphae. Similarly, the larger aerial mycelium is always associated with the development of dark hyphae which become closely knit together to form a black leathery stroma upon, or just under, the surface of the medium and especially in the part of it below the slant when the medium of an old culture retires from contact with the glass of the tube. Stroma-formation in cultures with small aerial mycelium is less perfect and either later in appearance, or, in the majority of cases, altogether absent; it thus varies with the tendency of the strain to form a large or a small mycelium. In culture, stroma-formation follows the production of spores. Small fragments of stromatic tissue may simulate sclerotia, but true sclerotial formation has not been encountered. The pseudo-sclerotia are merely masses of hyphae, and they give rise to normal growths in culture. A dark-grey mycelium of the same type as the large white mycelium mentioned above appears at times. It develops the same black stroma, and it is associated with a large production of conidia. At other times,

the mycelium is entirely confined to the medium, the surface of which may then be, and often is, covered with pustules. Burger*, working with strains of *C. gloeosporioides*, was able to classify them into five morphological groups according to the variations exhibited in culture, but, so far as culture studies of *C. coffeanum* have been pursued, it is impossible to adopt a similar arrangement. Certain strains resemble each other strongly, but they do not continue to do so consistently, either on the same medium or on different media, and whether of the same generation or not. The types of growth are scattered, as it were, over all the strains, and they are therefore to be taken as typical of the species rather than of individual strains. In other words, differentiation of the various strains on morphological features which are repeated with regularity is not feasible.

In young cultures, the most common or normal conidial measurements are $15 \times 5 \mu$. As the age of the cultures increases, conidial sizes extend to $12{\cdot}5–20 \times 4–5 \mu$ with a limit of $25 \times 7{\cdot}5 \mu$. Such out-sized conidia as the last have appeared in the majority of the strains and on various media, and they must therefore be regarded as characteristic of *C. coffeanum* in culture rather than as the outcome of temporarily favourable conditions. They are, however, always few in number; when sown, they give growths with normal spores. The normal conidium is rounded at both ends, although the attachment-end is usually slightly narrower than the free end, but occasional crops of conidia which are pointed at one end and rounded at the other have been encountered. They have occurred in the *arabica* coffee leaf brown blight, papaw fruit, cotton seedling anthracnose and cotton boll strains, and, since they have been confined to potato media, their shape is in all probability due to conditions of growth. Similarly, irregularly shaped conidia have been found only on potato agar. The pink or flesh-coloured pustules of conidia vary in size, for a pustule may be derived from one acervulus or from the coalescence of the products of several acervuli. The pustules are usually persistent and are characteristic in varying degree of all the strains of *C. coffeanum*. They have not diminished in quantity in successive generations of the majority of the strains when grown on different media, but several of the strains have been found to relapse into infertility when grown continuously on the same medium. It should be noted, however, that none of the strains has been taken beyond the fourth or fifth generation. Non-fertile strains have been brought back to a conidial producing condition by transfers to sterilised beans, boiled rice or plugs of sweet potato. This

* Loc. cit. 725.

behaviour seems to imply a certain morphological instability in the strains, but it is to be noted that the supposed instability is the result of an unfavourable environment and that it disappears when the environment is modified.

The appressoria are dark brown in colour, and the majority of them are simple, spherical or roughly pyriform in shape, and about 6–7 μ in diameter. When they are of irregular shape, they may be 12·5 μ in length. The terminal cell of the hypha or germ-tube bearing an appressorium is often swollen, and it may darken in colour and so form with the original appressorium a two-celled structure. At other times, the simple appressorium enlarges, assumes an irregular shape, develops septa, and so becomes a compound appressorium. Examination of the contents of the drop of nutrient medium used in inoculation experiments, whether successful or not, shows that the appressoria formed on germination of the conidia of the inoculum are indistinguishable from those formed in solid media or in hanging-drop cultures.

Various occurrences of *Glomerella cingulata* have already been noted. Certain strains have never yielded the perithecial form, but, in spite of this, all the strains are regarded as conidial forms of the one Ascomycete. Young ascospores are hyaline and measure 15–20 × 4·5–6 μ. When older, they become pale brown in colour and one-septate, and they may then measure up to 25 μ in length. The perithecia vary in length and breadth, but the majority are about 300 μ long.

A general survey of the above cultural characteristics points to the majority being the result of qualities or tendencies inherent in the various strains. Certain of them may have to be brought to light by mechanical means, but mostly they are constant enough to be raised to the rank of characters of the species *C. coffeanum*. It is to be noted that such variations as do occur are not marked enough either to enable special morphological forms to be set up or to lead to an arrangement which may be correlated with a physiological classification of the strains. A careful search has not revealed up to the present the occurrence of a saltation in *C. coffeanum*, and there has been no evidence of the splitting of a strain into morphological substrains. It appears that the morphological facies of the strains are comparatively well-marked and confined within definite limits which must therefore be taken to connote the species *C. coffeanum*.

Cross-inoculations and Discussion of Results.

The above-recorded study of the morphology of *C. coffeanum* showed clearly that it was necessary to seek for a non-morphological basis of distinction between the strains, and it was hoped

that an investigation into their physiological behaviour would throw such light upon their constitution that they might be placed in well-defined groups and that some of them at least might be labelled as forms of *C. coffeanum* after the manner of the races within certain well-known species of rusts.

Throughout the inoculation experiments care was taken that the conidia from the various strains were viable when used as inocula. They were tested in hanging-drops of the same medium as was used to convey the inoculum into contact with the intended host, viz. dilute Richards' solution and sterile weak cane-sugar solution. Distilled water was not used because the nutrient solution proved more provocative of rapid spore-germination. Young freshly-produced spores of early generations were found to give the most vigorous and rapid germination and to form appressoria in the largest numbers, and they were employed in small quantities in small infection-drops. The comparative amount of germination in hanging-drop tests did not seem to be affected by the number of spores in the drop; in other words, growth was as vigorous in a crowded drop as in one with few conidia. It was also noted that germination and the formation of appressoria were frequently as vigorous in a strain of supposed saprophytic origin as in a parasitic strain. The rôle of the appressorium in infection has been shown to be a mechanical one*, and it is presumed that the appressorium of *C. coffeanum* does not differ in function from its kind. If the formation of appressoria by a strain is assumed to indicate potential parasitism in that strain in the sense that it possesses the means of forcing an entrance into the tissues of a host, it follows that the ultimate responsibility for parasitism ought to be laid upon the host plant and its powers of resistance to attack or upon the conditions under which the fungus comes into contact with its host rather than upon the fungus itself. The act of parasitism consists of two parts, the first being actual penetration and the second the establishment and development of the parasite within its host: it is thus possible that an immune or resistant host may beat off the attack of a parasite at one or other of the stages. It has been found in these experiments that the advance of the fungus from the infection-drop into the host may be arrested at either of two points; the appressoria may fail to penetrate the host cuticle, or they may penetrate and give rise to infection hyphae which presumably meet with such a barrier to their advance that they die off and fail to establish the fungus within the tissues. In the first case, the host cuticle at the point of contact with the infection-drop is unaltered; in the second, it may be marked by a red-brown or

* V. H. Blackman, Brit. Assocn. Report, 1924, Sect. K, Pres. Address.

brown discoloured area from which the fungus cannot be recovered and in which its presence has not been detected. It may be added that appressoria taken from the infection-drops of unsuccessful inoculations can be germinated, a fact which points to the inhibition of penetration being due to an influence outside the appressoria themselves. Unsuccessful inoculations are therefore characterised by the failure of the fungus to penetrate and establish itself in the host tissue despite the presence of viable appressoria in the infection-drop or the initial penetration by the appressoria, and the above supposition regarding the responsibility for parasitism seems to be supported by these facts. In other words, a strain may be assumed to be potentially parasitic so long as the germination of its conidia gives rise to the formation of appressoria. Experimental results, however, do not agree *in toto* with this hypothesis, which is evidently too simple to fit the case. The strains used in these experiments may be equipped with similar appressoria and they may be brought into contact with susceptible hosts under similar circumstances, but it does not follow that they will of necessity react alike. Each strain must therefore be credited with the possession of a distinct physiological character or characters which are apparently independent of such a morphological character as the presence of an appressoriun. It is impossible, therefore, to guarantee to each strain in any given test the internal and external conditions absolutely necessary to its parasitism, and it is, on that account, the more essential to ensure to the strain every opportunity of doing, so to speak, its best. Care was therefore taken to use only the best available inoculum in the experiments, that is, conidia from young and vigorous growths of the first and second generations, and to provide the fungus with conditions favourable to its attack. In this way, at least two sources of variation in results were brought within control, as far as could be. It was also a regular practice in the experiments to attempt to give each strain equal opportunities of infecting the various hosts by setting up the same number of infection-drops of each, by endeavouring to ensure to each infection-drop a similar number of viable conidia through the preliminary use of hanging-drops, and by choosing for inoculation leaves and other parts of the same ages. In the cases of coffee leaves, for example, young leaves are probably less susceptible to *C. coffeanum* than older leaves, and only the latter therefore were used. It should be added that in leaf inoculations it was possible to test two and often more than two strains on one plant, a method which aided in the control of the conditions of infection. In fact, as many as six strains have been tested on a single plant, and, with large leaves like those of vanilla or *robusta* coffee, two

strains have been tested frequently on a single leaf. Again, there is no doubt that host plants, even of the same species, vary to a great extent in their resistance to an invading fungus, but no conspicuous example of such variation within a single species was encountered among the plants of these experiments. If it happened that a young plant of, say, *arabica* coffee appeared to be immune or resistant to certain strains tested upon its leaves, a further test with a strain that had been proved to cause leaf blotch in other *arabica* plants always showed that the immunity or resistance was only temporary or confined to the reaction of the plant to certain strains. The only examples of strongly resistant host species were those of the vanilla leaves and unwounded cotton bolls used in the experiments, not one of which was infected by any of the strains tested upon it, although the experiments were repeated three times. Similar cotton bolls, it may be mentioned, were infected easily by a strain of *Colletotrichum Gossypii* from Trinidad. A result was regarded as positive or, in other words, an inoculation was successful, when appropriate and typical symptoms appeared and when *C. coffeanum* was duly recovered from the material. All the experimental plants were grown in tins, and all were kept in light shade out of doors except at the time of actual inoculation and for a space of forty-eight hours immediately after, during which period the plants were covered with bell-jars. The incubation period was the same in all experiments, and it was considered to be of sufficient length because no conidia were used unless they showed a twenty to twenty-five per cent. germination in twenty-four hours. When detached parts like cotton bolls, coffee berries and fruits were inoculated, the cut ends of the stalks were sealed with beeswax, and the material was allowed an incubation period in a moist atmosphere in glass dishes and was afterwards kept under cover. All leaf and bean-pod inoculations were made on growing plants, and inoculated berries and fruits that turned brown and lost their general freshness more quickly than the controls were discarded. In order to ensure that the fungus was not aided by a previous killing of the plant surface by chemical or physical action on the part of the medium in which the conidia were suspended, drops of the media used were placed as controls alongside the inocula, and, in the few cases where the medium appeared to cause the death or degeneration of the underlying areas of plant tissue, the results were disregarded. Care was taken also to see that inoculated surfaces were wetted by the infection-drops.

It has been doubted if infection experiments of the nature of those related here are of much value in establishing patho-

Table.

| STRAINS | | | | HOSTS | | | |

genicity in, or relationship between, strains and species. Their value must vary with the conditions under which the experiments are conducted, and it follows that it is increased when the variable factors in fungus, host, and conditions of infection are brought under the greatest possible control. No doubt the control can be made more complete, but the experimental conditions described above are sufficiently standardised and simplified to enable the end in view to be attained and the results to be taken as genuine expressions of the physiological nature of the tested strains under known conditions *at a given moment*. This time reservation was originally enforced by the fact that the primary aim of investigation into the occurrence of such a species as is discussed here is usually a practical one and that, for the immediate end in view, it is necessary to consider first and foremost the nature of a strain as it is found *in situ*, that is, in infection tests carried out without delay—but additional reasons for its mention are given later. The scope of the work indicated in the table does not extend beyond those limits except in so far as it includes an effort to determine by cross-inoculations the reactions of the strains towards other hosts than the original ones with a view to their physiological classification; the results and conclusions are not presumed to have other than a local application. The Table gives the results of the inoculation and cross-inoculation experiments. A + sign denotes a positive result, and the nature of the affection caused is indicated at the top of each host column. A − sign means that the host in question was not infected by the strain in question, and a blank space means that no experiment was conducted or that the result was doubtful and was not considered of value. The symbols P, WP and S are used only conventionally and as a convenience to refer to the apparent nature of each strain at its isolation, and mean respectively parasitic, weakly parasitic and saprophytic.

The results of the direct inoculations have been mentioned in the paragraphs dealing with the hosts of *C. coffeanum* and are not all included in the Table. When the results of the cross-inoculations come to be considered, the first line of enquiry is perhaps that directed towards showing whether the experiments bring to light the existence of well-marked biological races in *C. coffeanum*. Several of the strains, particularly those marked P, have such a distinctive origin that they might be expected to behave in a distinctive manner, but, when the inoculation results are considered, many are seen to be unexpected. For example, the *arabica* coffee leaf brown blight strain of *C. coffeanum* shows a distinct partiality to coffee substrata, but it is also strictly parasitic on Pará leaves and bean pods and it causes a

mango, chilli and avocado pear ripe rot by penetrating the skins of the fruits, and a papaw ripe rot with the help of a wound entrance. At the same time, it is incapable of invading *arabica* berries through the unbroken skin, and it is partial to the leaves and wounded berries of another species of coffee, viz. *robusta*. The behaviour of the *arabica* berry strain differs from that of the leaf strain inasmuch as it is parasitic on orange leaves and non-parasitic on bean pods and Pará leaves and it can penetrate both the skin of a ripe papaw fruit and a ripe *arabica* berry without help. Similarly, the *robusta* coffee leaf and berry strains do not behave in the same fashion, for either is parasitic when the other gives negative results. On the whole, the *robusta* berry strain is more aggressive than the *robusta* leaf strain, and, in that respect, it resembles the *arabica* leaf strain more than the *arabica* berry strain. Again, the behaviour of the *robusta* coffee leaf and berry strains towards *arabica* coffee leaves is more distinctive than that of the *arabica* strains towards *robusta* leaves, but, on the whole, the results of the experiments with the four presumably parasitic coffee strains vary to such an extent that the distinctive physiological behaviour that may be expected from strains drawn from closely related sources is wanting in them whether they are considered individually or in the mass. The tea leaf brown blight strain shows distinctive behaviour in being the only strain to infect the leaves of its own host, and then only in upper-surface inoculations, but, at the same time, it is able to penetrate the uninjured skin of ripe *arabica* coffee berries and ripe mango and avocado fruits and to blight Pará leaves. It can live also upon cotton seeds and ripe *robusta* coffee berries. The orange leaf strain behaves in a manner similar to the tea leaf strain with regard to its own and the other hosts except *arabica* coffee berries and cotton seeds. The strain derived from cotton seedling anthracnose can reproduce the anthracnose through pricked seeds, can live upon *arabica* coffee berries and can cause, curiously enough, anthracnose of French beans. The bean anthracnose strain, while unable to infect coffee leaves and berries of either kind, can grow upon cotton seeds and papaw fruit, can penetrate the unbroken skin of ripe chilli and avocado fruits and can blight Pará leaves. Its physiological behaviour is therefore not very distinctive. The two WP strains from mango and papaw fruit ripe rots differ to a considerable extent in their behaviour. The former can attack bean pods and both wounded and unwounded *robusta* berries and the latter Pará and orange leaves, unripe mango fruit, ripe *arabica* berries and pricked cotton seeds and *robusta* berries, while both can parasitise *robusta* coffee leaves. A good example of a so-called S strain is that derived from

healthy *robusta* coffee material. When tested, it can infect both *arabica* and *robusta* coffee leaves, can invade bean pods and ripe avocado fruits, and can live upon coffee berries, cotton seeds and papaw fruit with the help of wound entrances. A second S strain, that from the discoloured skin of a cotton boll, can attack *arabica* coffee, orange and Pará leaves and unripe mango fruit, can penetrate the skin of ripe mango and avocado fruit and can grow upon wounded *robusta* coffee berries and cotton seed. The origin of the vanilla flower bud strain is doubtfully S, and the strain itself is certainly parasitic on bean pods, Pará leaves and ripe avocado and mango fruits. It can also penetrate into wounded cotton seed, papaw fruits and ripe *robusta* coffee berries. The ground-nut leaf strain behaves in a manner consistent with its supposed nature even when it penetrates wounded ripe *arabica* and *robusta* berries, but its ability to cause brown blight on unwounded *arabica* berries, albeit ripe fruits, shows that it can behave as a parasite on occasion. The remaining S strain is, like the ground-nut leaf strain, truly parasitic on ripe *arabica* berries. It also penetrates wounded *arabica* and *robusta* berries, and it can cause ripe rots of unwounded mango and avocado fruits.

If biological races are characterised by their obligate parasitism on certain hosts and their refusal to infect other hosts, it is apparent from the results of the above cross-inoculation experiments that none of the strains studied deserves to be set up as a distinct race. The coffee strains, for example, are not even obligate parasites on their own hosts, and they do not behave towards other hosts as a well-defined physiological group. If, again, the standard of behaviour expected from a biological race be lowered to permit of an obligate parasitism on one host and a weaker parasitism on others, the tea leaf strain alone comes near to fulfilling those conditions, but even it cannot be labelled as a truly selective strain because there is no proof that it is really more strongly parasitic on its own host than on the others it can attack. If it be admitted for the moment that educability of fungi is possible, then the most that can be said of it is that the particular strain used in the experiments has progressed further towards acquiring the habit of selective parasitism than any of the others. On the same condition, it may be added that, as far as the results of the experiments may be taken to indicate the physiological natures of the tested strains, none of them has begun to acquire the power to penetrate green cotton bolls and so become capable of causing boll anthracnose, and that, on the other hand, a large proportion of them is able to attack bean pods, a substratum which may be expected to require a specialised race for its penetration.

There is, on the whole, a remarkable lack of distinctive behaviour among the strains, and it is impossible to apply to any of them such a test of exact relationship as can be applied with success to strains of, for example, *Puccinia graminis*, a test in which infection by a given strain implies that the host infected must be a certain pure-line wheat and no other.

It is evident that certain of the host plants or parts of plants used in the experiments are more susceptible to penetration by *C. coffeanum* than others. Among the most susceptible are Pará leaves and ripe avocado and mango fruits. French bean pods are surprisingly susceptible, and *robusta* coffee leaves are more susceptible than *arabica* leaves. In these cases, however, emphasis may be laid on the necessity for penetration before infection can take place, and it follows that a strain may be regarded as truly parasitic at the moment it is able to penetrate any one or more of these host parts. The susceptibility factors of the different hosts may be left temporarily out of account when all the strains are tested on each of these hosts under similar conditions, and the results of such one-host tests may be regarded as an index to the character of each strain. The behaviour of the strains may thus be examined from the point of view of the physiological origin of each (denoted by the symbols P, WP and S) with a view to showing whether they retain in a marked manner their supposed original character. With regard to the six susceptible hosts or parts mentioned above, the *arabica* coffee leaf strain alone can parasitise all of them, while the remaining three coffee strains infect either three or four of them with a certain amount of unanimity. The behaviour of the other P strains varies between the three similar infections by the tea leaf and orange leaf strains, the single bean pod infection by the cotton seedling anthracnose strain, and the three infections of the bean anthracnose strain. The two so-called WP strains each parasitise three of the six hosts, two out of the three being alike in both cases. The behaviour of the supposed saprophytic strains is perhaps more interesting than that of the parasitic strains inasmuch as those from the healthy *robusta* coffee twig, the discoloured cotton boll and the vanilla flower bud can behave in a truly parasitic manner, although ripe avocado fruits are the only host common to all three strains. The orange twig strain can penetrate ripe avocado and mango fruits, and the ground-nut leaf strain is non-parasitic in all six tests. When the behaviour of the strains is regarded from what may be termed the weakly-parasitic point of view, that is, towards such hosts as wounded *arabica* and *robusta* coffee berries, cotton seeds and papaw fruit, it is seen that only the *arabica* coffee leaf and the tea leaf strains out of the eight

supposed P strains infect all four hosts, and that the four coffee strains do not behave in a similar manner. The P strains are on the whole less strongly parasitic in these cases than in those where penetration of the host is a preliminary to parasitism. The WP strains may be expected to grow upon all four substrata, but they do not do so. On the other hand, one of the S strains, that from the *robusta* coffee twig, grows upon all the substrata, while the others are parasitic in a degree equal to that of certain of the P strains. If the conditions on which the strains are judged are modified to include more rigorous tests of parasitism, viz. the ability to penetrate what appear to be the least susceptible hosts, unripe mango fruit and unwounded ripe chilli pods, it is found that the only strain which is successful in both tests is the P strain from *robusta* coffee berry brown blight. Two other parasitic strains, those from *arabica* coffee leaf brown blight and bean anthracnose, are successful in one test only, while the remaining so-called P strains do not penetrate either substratum. One of the WP strains is parasitic on the green mango fruit, and only one of the five S strains succeeds in attacking one of the two hosts, the unripe mango. The results of these last tests show that the parasitic strains are successful in one test out of four and that the saprophytic strains are successful in only one test out of ten, and may be taken to prove that an originally parasitic or saprophytic strain tends to retain its parasitic or saprophytic nature. Such a deduction, however, is not supported by a similar analysis of the results of the tests on the six hosts which are supposed to be more susceptible than the green mangoes and chilli pods or of the tests on wounded host parts. In any case, the supposedly more rigorous tests are hardly numerous enough to justify deductions from them. It should be added that, for reasons which are indicated later, the results do not lend themselves to statistical treatment, and that it is realised that the grounds on which a strain is labelled P, WP or S are open to criticism. It can only be concluded that there is no proof that the original nature of a strain has any influence on its subsequent behaviour, and it follows that the attempt to denote the nature of each strain at its isolation by a label which is intended to indicate a permanent quality has no scientific basis.

It might have been of interest to enquire whether a group of related strains like the four derived from coffee leaves and berries shows a restricted or limited choice of host substrata, but it is evident that no stress can be put upon the behaviour of strains which do not behave consistently towards their own hosts. All that may be said of them is that they have an affinity for ripe mango and avocado fruit, and even that statement has little

value since these fruits may be suspected of being susceptible to *C. coffeanum*. There is a general lack of direction of attack among all the tested strains, a state of affairs which is perhaps a natural accompaniment of the lack of physiological specialisation.

It would be easy to close the discussion at this point by concluding that *Colletotrichum coffeanum* is, under the conditions related, a composite species made up of numerous units which are not distinguishable from each other on either morphological or physiological grounds, but, unfortunately, that statement does not really explain the nature of the fungus which, after all, it was the object of this investigation to disclose. The fungus may be regarded as a plastic organism of which the morphological aspect is relatively constant while its physiological aspect varies with changes in the environment, and it may be assumed that its parasitism is conditioned by the presence of the fungus among hosts which are more or less susceptible to its attacks under environmental conditions which are more or less favourable to either parasite or host. If this interpretation of its nature is taken to mean that *C. coffeanum* is always lying in wait, as it were, for opportunities of attack that are granted or denied to it by temporarily favourable or unfavourable conditions, it may be taken also to imply that the strains of the fungus are always potentially parasitic both in themselves, that is, each towards its own host, and also towards other hosts. In other words, it may be assumed that each strain of *C. coffeanum* is not only a stable morphological unit but also a discrete physiological entity which can and ought to behave in a certain definite manner under certain known environmental conditions. That it does not do so is proved by the mixed and almost erratic results of the cross-inoculations which, it may be emphasised, were carried out under controlled and constant conditions favourable to the fungus, by the existence in nature of apparently saprophytic strains, and by the fact that in no case has any one strain which yields a + result been found capable of one hundred per cent. success in causing infection. A + result implies only that a given strain has infected a given host at least once out of the number of opportunities afforded it, and it does not infer any definite percentage of infection. Further, it has been found that the percentages of + results from any given strain diminish with the age of the strain in culture and with the use of infection conidia drawn from generations beyond the first and second. For example, tests of the *robusta* coffee leaf brown blight strain on its own host give + results which vary from a fifty per cent. infection with conidia from a young culture (seven days or less of age) to a nought per

cent. infection with conidia from a culture four weeks old, and, in certain cases, no infection at all has been got with conidia from the fourth or fifth generation of a strain which behaved in a different manner in its first and second generations. An alteration in the conditions of experiment favourable to the fungus, for example, a lengthening of the incubation period under the bell-jar, does not affect these results. The results of a given set of experiments cannot be expected to repeat themselves unless the inoculations are carried out with material from young cultures of an early generation, and, in any case, it has been found that different isolations of a given strain cannot be guaranteed to behave in an exactly similar manner. There were, therefore, extra reasons in the experiments for using conidia from what have been called young and vigorous growths and also for the mention of a time reservation in the account of the conditions of experiment.

Certain of the above facts may be expressed in a different manner by saying that the strains of *C. coffeanum* lose with age their capacity for parasitism, and on the whole they seem to imply that the strains in question are genetically unstable. It has already been shown that the strains do not behave as physiological entities. As for their supposed instability, it can be said that there is a steadily accumulating body of evidence in favour of the view that genetic stability is as constant a character of fungi as of higher plants. If that view be accepted, it is necessary to premise the existence of discrete physiological strains capable of different types of behaviour within any single isolation of *C. coffeanum*. No strain is to be regarded, then, as a simple physiological entity, even at its point of origin, and each may be what Brierley has called a "genetic population."* No immediate proof of the presence of more than one physiological strain within a morphological unit of *C. coffeanum* can yet be advanced, but the writer hopes to continue the study of the fungus. In the meantime, the "genetic population" explanation fits the facts and throws light upon the curious behaviour of the strains of the fungus under discussion. It also explains the state of affairs in the field where plant disease due to *C. coffeanum* ought to be more in evidence than it actually is. Hosts and fungus have a common geographical distribution, and natural conditions, particularly cool dewy nights and misty mornings, are favourable to fungus attack. No doubt, also, certain of the substrata on which *C. coffeanum* is found are susceptible to its advances and open to its attack. The fungus may therefore be supposed to consist of numerous physiological strains of different natures living side

* Report of the Imper. Bot. Conference, London, 1924, p. 117.

by side, certain of which from time to time find suitable opportunities of adopting the kind of life which lies within their physiological capabilities, and it follows that the limiting factors governing local *C. coffeanum* disease are susceptibility of the host part exposed to attack and the presence of a strain possessing certain germinal qualities.

Conclusion.

It was made clear at the beginning of these notes that the species name *C. coffeanum* was adopted only for reasons of local convenience, and the fact that the forms which come under the scope of the present inquiry can be included under the one name on morphological grounds has been emphasised. The majority of them, if not all, are regarded as conidial forms of *Glomerella cingulata*, and relationship with that Ascomycete has been proved for many of them. It was also mentioned that specific names other than *C. coffeanum* might be used with equal or greater justification to designate the various forms or all of them, and it follows that the study of isolated occurrences of the fungus with special reference to the host of each instead of in the mass would lead to the use of the other specific names. Moreover, both the generic names *Colletotrichum* and *Gloeosporium* would have to be used. In such circumstances, the fungus on coffee leaves and berries might be called *C. incarnatum* Zimm., that on cacao *C. incarnatum* or *C. theobromicolum* Del., that on tea *C. Camelliae* Mass., that on citrus, mango and avocado pear *C. gloeosporioides* (Penz.) Sacc., that on chillies *C. piperatum* Ell. and Everh. or *C. nigrum* Ell. and Hals., and that on papaw and figs *C. Caricae* Stev. and Hall. The foregoing list of names might be extended to include others, but it is confined meantime to those species whose connection with *Glomerella cingulata* has been proved either here or elsewhere. Among other species that may come into question are *C. Heveae* Petch, *C. Musarum* Cke. and Mass. and *C. Lindemuthianum* Br. and Cav. *C. Gossypii* Southw. is definitely excluded because the Trinidad strain already referred to was found to differ consistently in culture from *C. coffeanum* in the dry powdery appearance it imparted to the surface of the medium. The position of *C. Lindemuthianum*, again, is less clearly defined than that of *C. Gossypii*. In both the occurrences on bean plants mentioned under a previous heading, the local fungus was indistinguishable from *C. coffeanum* in nature and in culture, and, in one of them, that in which the fungus was associated saprophytically with a *Sclerotium bataticola* wilt of beans, an isolation of it was identified by the Imperial Bureau of Mycology as *C. Lindemuthianum*. The same

form produced a *Glomerella* stage which was indistinguishable from that of other *C. coffeanum* forms. The bean pod anthracnose strain, however, has not formed the perfect stage and has not been compared with material from other sources, and *C. Lindemuthianum* therefore is in the meantime excluded from the list. It may be added that, in the separate descriptions of the species of the above list, the morphological details which vary from the details of *C. coffeanum*, for example, sizes of acervuli and conidia, colour of conidial masses, presence or absence and sizes of setae and also types of appressoria, are repeated and paralleled here and there in the occurrences of *C. coffeanum* both in nature and culture. It is clear that the local use of the above names for conidial forms which resemble each other strongly and which behave in the manner of *C. coffeanum* is to be deprecated, and the writer is of opinion that the best method of naming them is to apply the conidial name which has priority among those which have a proved connection with *Glomerella cingulata*, namely, *C. gloeosporioides*. Distinct biological races can then be designated as forms of the species, for example, forma *Camelliae*. The fact that no biological races have been found yet does not preclude their undiscovered existence in the present or, as some authorities would admit and others deny, the possibility of their evolution in the future.

Summary.

1. Various occurrences of a species of *Colletotrichum* which have common morphological features in nature and culture are outlined.

2. An attempt is made to find whether the strains of the *Colletotrichum* are characterised by constant physiological qualities which lead to consistent behaviour and a definite relationship between them and their host or hosts.

3. It is found that the strains do not behave as physiological entities and that they appear to be genetically unstable. An explanation of their physiological variability is advanced, and it is suggested that they should be named in a certain way.

BLACK RUST IN SCOTLAND.

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(With Plate IV.)

Introduction.

History.

Among the rusts of cereals, that known as "Black Rust" has long been recognised as a disease causing the most widespread and serious loss. The name *Puccinia graminis* was given to the teleutospore stage of this fungus in 1797 by Persoon and at the same time the rust on barberry was named *Aecidium Berberidis* by the same investigator, who did not associate the two diseases. The uredospore stage was called *Trichobasis linearis* Lév.

In 1864 de Bary as a result of infection experiments, used the name *Puccinia graminis* to include all three stages of Black Rust and in 1881–2 de Bary's results were confirmed by Plowright(6, 7). Early records of the distribution of Black Rust in Scotland are given by Stevenson(10) in 1879. Trail in 1890(11) published his *Revision of the Uredineae of Scotland* and in this he records the aecidial stage on the barberry for the Clyde, Forth, Tay, Dee, Moray and Orkney districts the other stages being found in addition in Ross but not in Orkney.

Eriksson in 1894 gave the first account of specialisation in Black Rust. Since then Eriksson(1, 2) and Henning and Stakman and Piemeisel(8, 9) have published several papers on the subject. According to these investigators there are seven biologic forms of the rust in the States; reference is also made to an Australian form of *Puccinia graminis Tritici*. These forms are as follows:

Puccinia graminis Tritici Erikss. & Henn. (American form).
" " " (Australian form).
Puccinia graminis Tritici compacti Stak. & Piem.
Puccinia graminis Secalis Erikss. & Henn.
Puccinia graminis Avenae Erikss. & Henn.
Puccinia graminis Phlei-pratensis Stak. & Piem.
Puccinia graminis Agrostidis Erikss.
Puccinia graminis poae Erikss. & Henn.

In England Mehta, working at Cambridge(5) found Black Rust present on wheat, barley and couch. His experiments showed these infections to belong to two biologic forms—*Puccinia graminis Tritici* on wheat and *Puccinia graminis Secalis* on barley and couch.

Scope of the present investigation.

Though the rust has long been known in Scotland, no effort appears previously to have been made to define its economic importance. The present investigation aims at indicating the forms of the rust which occur in Scotland.

It appears that no recent records have been made from some of the districts mentioned by Stevenson and Trail but no extensive study of the present distribution has yet been made.

In 1914 *Puccinia graminis* was observed on barberry and *Agrostis vulgaris* near Tyndrum in Argyllshire. Since then the rust has also been noted in a few other scattered localities in Scotland, namely Inverness-shire, Fifeshire, Midlothian, Berwickshire, Peeblesshire and Dumfriesshire. The aecidial host *Berberis vulgaris* is probably not so common as it once was, but is found widely distributed in a healthy condition over the southern half of Scotland.

Experimental methods.

In 1924 it was decided to investigate the specialisation of the forms of Black Rust which has been found in Midlothian and Dumfriesshire. In addition to field observations, experiments were carried out at the Royal Botanic Garden, Edinburgh, in the field and laboratory.

The following results were obtained from infection experiments:

Midlothian: wheat, barley, rye*, *Agropyron repens**, *Bromus sterilis* infected.
Berwickshire: oats, barley, *Agropyron repens* infected.
Dumfriesshire: oats*, *Agropyron repens**, *Agrostis vulgaris*, *Dactylis glomerata* infected.
Argyllshire: *Agrostis vulgaris* infected.

Agrostis vulgaris, *Dactylis glomerata*, *Phleum pratense*, *Arrhenatherum avenaceum*, *Lolium perenne*, *Poa nemoralis* and *Festuca elatior* were present but not infected in Midlothian: these species and also wheat were present but not infected in Berwickshire.

The teleutospore stage on those species marked with an asterisk served as inocula. The healthy barberries for the experiments were obtained from the Royal Botanic Garden, Edinburgh. The infected Gramineae used for inocula were collected in autumn and allowed to over-winter outside the laboratory, care being taken to prevent cross contamination.

As regards the infections with the Dumfriesshire material—teleutospores on oats and couch—the following is an outline of the methods:

In out-of-door infection from rusted oat straw, this was allowed to winter under wire netting on the ground immediately beneath six healthy barberry bushes. In the spring the rusted straw was tied to the barberry branches before the buds opened. Some of these branches were enclosed in glass flasks to increase the chances of infection (Pl. IV, fig. 1). The flasks were plugged with cotton wool, and the contents were kept moist throughout the season by means of a spray.

Teleutospores from the infected straw were examined for germination in the laboratory at intervals from January till April. No germination was observed either in hanging drops or in a moist Petri dish until about the second week of April.

For infection from couch, the same methods were adopted as regards attachment of the rusted straw to the branches of six barberry bushes and the enclosure of some of these branches in glass flasks.

When teleutospore germination was found to take place in spring, laboratory experiments were undertaken. Two potted barberry bushes were infected with oat rust, and one with couch rust, by tying the rusted straw round young shoots (Pl. IV, fig. 2) and also by placing teleutospores on the moistened leaves. The plants were covered with bell-jars and kept moist by means of a spray. Healthy barberries were also infected indoors from rusted rye and couch obtained in Midlothian. The method of infection was similar to that with the Dumfriesshire material.

In the laboratory the method of infection experiments with the cereals and grasses was as follows: Grains of the cereals and roots of healthy grasses were grown in pots under bell-jars. When the barberries, artifically infected, showed ripe aecidia, these were transferred by means of a brush to the moistened leaves. Later on, in order to save space and to increase the chances of infection, the cereals and grasses to be tested for any form of the rust were placed under the same bell-jar as an infected barberry (Pl. IV, fig. 3).

Out-of-doors, grain of rye, barley and wheat were sown in an oat field immediately behind a naturally infected barberry

hedge in Midlothian near which in the previous year only couch was found rusted. Oats, *Agrostis vulgaris* and *Agropyron repens* were grown out-of-doors at the Royal Botanic Garden, Edinburgh and infected artificially with aecidiospores from artifically infected barberries. Owing to the amount of rain at the time of inoculation it was necessary to cover the plants with bell-jars.

Results and Specialisation.

The results of inoculation experiments with aecidiospores from barberries, which had been infected from teleutospores from *Agropyron repens*, were that material from Midlothian (April 7th, 1925) and Dumfriesshire (April 8th) barley, rye and *Agropyron repens* gave positive results: wheat, oats, *Agrostis vulgaris*, *Dactylis glomerata* and *Phleum pratense* negative results.

Inoculations with aecidiospores from barberries which had been infected from teleutospores from rye, showed that with material from Midlothian (April 18th) barley, rye, *Agropyron repens*, were infected, while wheat, oats, *Agrostis vulgaris*, *Dactylis glomerata* and *Phleum pratense* were not infected.

The results of inoculations with aecidiospores from barberries which had been infected from teleutospores from oats, were that with material from Dumfriesshire (April 8th) oats and rye gave positive results; wheat, barley, *Agropyron repens*, *Agrostis vulgaris*, *Dactylis glomerata* and *Phleum pratense*.

The results show that the rust, originally from *Agropyron repens*, obtained from both Midlothian and Dumfriesshire, is capable of infecting the same hosts as the form on rye, and that the oat form of the rust infects oats and to a certain extent rye also.

The results of laboratory experiments with the rust on rye and *Agropyron repens* agree, so far as they have been carried out, with those obtained by Stakman and Piemeisel with *P. graminis Secalis*.

The form on oats, in so far as it only infected oats and, to a less extent rye, in the experiment is *P. graminis Avenae*.

Negative results were obtained in infection experiments with the above two forms on wheat, *Agrostis vulgaris*, *Phleum pratense* and *Dactylis glomerata*. *Bromus sterilis*, the only other grass found infected in the field has not been experimented with.

Barley, according to Stakman and Piemeisel, is, like rye, a host to a varying extent, for all seven recorded forms of the rust. With both the Midlothian and Dumfriesshire material of *P. graminis Secalis*, the degree of infection on barley in the field

and more especially in the laboratory would indicate that it bears this form, which is said most readily to infect it.

Specimens of infected wheat, obtained in Midlothian, evidently bear the form *P. graminis Tritici*; only one other form, *P. graminis Secalis*, is capable of attacking it and laboratory experiments with this form gave negative results.

No infection was obtained on *Agrostis vulgaris*, *Phleum pratense* and *Dactylis glomerata* with the *Secalis* or *Avenae* forms.

As regards the *Agrostis vulgaris* and *Phleum pratense*, these apparently bear two distinct forms, *P. graminis Agrostidis* and *P. graminis Phlei-pratensis* respectively. The former, so far as American experiments have shown, does not affect *Phleum pratense*, nor the latter *Agrostis vulgaris*. Both grasses have been weakly infected by artificial inoculation in the States, where also *A. vulgaris* was inoculated but not infected with *P. graminis Secalis*.

As regards the rusted *Dactylis*, this was found only in Dumfriesshire where it was growing alongside infected oats, *Agropyron repens*, *Agrostis vulgaris* and *Phleum pratense*. The *D. glomerata* growing alongside infected *A. repens* in Midlothian, and alongside infected oats and *A. repens* in Berwickshire was clean.

In the States *P. graminis Avenae* is found on *D. glomerata* in nature, but *P. graminis Secalis* was neither found on this grass in nature nor was it able to infect it after inoculation. The present infection experiments on *D. glomerata* in the laboratory gave negative results with both forms.

It is unlikely therefore that the *Dactylis* from Dumfriesshire bore either of these two forms. The only other possible forms that it could have borne are those on *Agrostis vulgaris* and *Phleum pratense*. *Dactylis* has been stated to be susceptible to *P. graminis Agrostidis* in the laboratory, but to be a host in nature for *P. graminis Phlei-pratensis*. Probably because the *Dactylis glomerata* bore the form *P. graminis Phlei-pratensis*.

So far, therefore, as observations have been made and experiments carried out, these indicate that the following five forms of *P. graminis* occur in Scotland:

P. graminis Tritici Erikss. & Henn.
P. graminis Secalis Erikss. & Henn.
P. graminis Avenae Erikss. & Henn.
P. graminis Phlei-pratensis Stak. & Piem.
P. graminis Agrostidis Erikss.

Economic Importance of Black Rust and Effect of Barberry Eradication.

The destructive effect of the fungus on cereals would account for attention being drawn to it since early times. Centuries ago it was observed that a definite relationship existed between the rust on barberry and the Black Rust on cereals; also that the eradication of barberry bushes from near infected fields resulted, in temperate climates at any rate, in a disappearance of the rust on cereals.

Only within recent years, however, have any statistics been obtained on the loss attributable to *Puccinia graminis*. In the United States of America, Canada and Australia estimates indicate that the damage due to this rust alone amounts to millions of pounds yearly. In Denmark the rust was, until the recent measures for control were undertaken, a great source of loss. In England and Wales the rust is said to injure wheat seriously, causing the grain to be small and shrivelled, and even to render crops worthless. In England the spores of the fungus are said to spread the disease for many miles, and eradication of the barberry has been recommended.

In Scotland no attacks on an epidemic scale have been recorded; and until a complete survey has been made, it is not possible to state the amount of loss. Judging from the extent of the rust in the localities in which it has been recently observed, it would appear that the rust may spread to a distance of about one mile from affected barberry during the summer; but that the amount of rust diminishes rapidly at a short distance from the affected bushes.

A number of observations were made in Midlothian on the distribution of the rust and the time of infection of a number of grasses. The results are given in the Table below.

Table.

Host Plant	Distance from infected Barberry	Infection July	Infection September
Agropyron repens	Immediately below	+	+
,,	200 yards	+	+
,,	1 mile	–	+
Barley	Immediately below	+	+
,,	15 yards	–	+
,,	1 mile	–	–
Rye	Immediately below	+	+
,,	1 mile	–	+
Wheat	Immediately below	–	+
,,	1 mile	–	+

From the above Table it is evident that the barberry carried a double infection, viz. *P. graminis Secalis* and *P. graminis Tritici.*

Of the hosts infected by the former *Agropyron repens* appears to be the most susceptible and the first to be infected although even this species was not infected at a distance of one mile until September. Rye is the next in order of susceptibility and barley least susceptible as it was not affected in July even as close as fifteen yards. It would appear therefore that the stock of *P. graminis Secalis* is maintained by the barberry and the couch immediately below it and that this form spreads through the summer on the couch to the rye and barley.

In Dumfriesshire in September, 1924, oats was found to be infected up to seven hundred yards from infected barberry but observations could not be made at greater distances; the amount of infection steadily diminished with increased distance.

As early as 1660 according to Loverdo(4) an Act of Parliament was passed at Rouen condemning the planting of the barberry in the vicinity of grain fields. A similar law according to Plowright was passed in Massachusetts in 1755 with favourable results.

The justification of this legislation was shown in 1864–5 when de Bary definitely proved the relationship of the rust on these two hosts.

The best example of the effect of barberry eradication is that started in Denmark in 1903. The beneficial results of that campaign are recorded by Ferdinandsen(3) in 1924. With the almost complete eradication of the barberry in Denmark the Black Rust on cereals has practically ceased to exist. In England similar control, on a smaller scale, is yielding satisfactory results.

Conclusions and Summary.

Black Rust occurs in Scotland in scattered areas and only in the immediate vicinity of affected barberries is the infection on cereals and grasses heavy. There is no evidence that the disease is carried over the winter by means of uredospores and destruction of barberries will almost certainly result in the disappearance of the disease.

Observations in the field show that the following five forms of *Puccinia graminis* are present in Scotland: sp. f. *Tritici, Secalis, Avenae, Agrostidis, Phlei-pratensis.*

Infection experiments with sp. f. *Secalis, Avenae* and *Agrostidis* indicate that these forms have the same powers of infection as have already been described in England and North America.

The authors wish to express their indebtedness to Dr Malcolm Wilson, Mrs N. L. Alcock, and Messrs J. S. L. Waldie and

Fig. 1.

Fig. 2.

Fig. 3

J. Fraser for assistance in obtaining material and for information about rusted crops and grasses; also to Mr Harrow, Curator of the Royal Botanic Garden, Edinburgh, for the provision of barberry plants and of ground for out-of-door experiments.

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EXPLANATION OF PLATE IV.

Fig. 1. Artificial infection of barberry out-of-doors. In the flask and on the ground are straws of couch bearing teleutospores of *Puccinia graminis*.
Fig. 2. Infection of barberry indoors. Straws bearing teleutospores are tied to the branches. A bell-jar covers the plant.
Fig. 3. Infection of cereals indoors. Four small pots in which cereals are growing are resting on a larger pot containing a barberry plant. The leaves of the cereals are thus growing among the leaves of the barberry, which bear aecidia.

A PRELIMINARY ACCOUNT OF A DISEASE OF GREEN COFFEE BERRIES IN KENYA COLONY.

By J. McDonald, D.F.C., B.Sc.

(Mycologist, Department of Agriculture, Kenya Colony.)

What is believed to be a previously unrecorded disease of coffee exists in Kenya Colony and has been the subject of investigation for some time. The main facts concerning its causation and control are now known but much work remains to be done in amplifying a number of points.

The disease, which is known locally as Black Berry or Coffee Berry Disease, was first reported at the end of 1922 and has

caused considerable annual losses, in some cases as much as seventy-five per cent. of the crop having been destroyed. Fortunately, it is known to occur only in two small districts, which are situated at altitudes of between six and seven thousand feet and characterised by an average annual rainfall of fifty to seventy inches, the greater part of which is spread fairly evenly over eight or nine months of the year.

Symptoms.

The disease is confined almost entirely to the berries, berry stalks and a small area of the twigs immediately adjacent to the bases of the berry stalks. The green berries are attacked at all ages, a small dark brown spot being the first symptom. This enlarges in area, becomes slightly sunken and eventually involves the whole berry, the pulp of which becomes brown, hard and brittle. Except for the fructifications of the fungus, the surface of the dried-up berries is smooth. Examination of the coffee beans shows that the one immediately under the point of infection becomes diseased very soon after the external spot appears, and that almost as soon as the pulp is completely involved, both beans are reduced to a shapeless, black, shrivelled condition. They then occupy very little of the internal space of the berry and are completely useless commercially. The berry stalks are soon quite desiccated and black, but the fungus does not appear to be able to progress more than a few millimetres along the twig. Many of the dead berries fall to the ground. The branches, however, are not killed and their leaves remain perfectly healthy in appearance.

In the field the pulp is often found to be covered with numerous minute black fructifications from which pink spore masses, becoming white with age, are produced. Microscopic examination shows the fructifications to be the acervuli of a species of *Colletotrichum*, morphologically indistinguishable from those of *Colletotrichum coffeanum* Noack. The acervuli contain dark brown, tapering setae, with four or fewer septa which measure 84–103μ in length. The spores are typical in shape and measure 13·4–18·5μ by 4·8–6·6μ with average dimensions of 15·1μ by 5·7μ.

There is reason to believe that the Coffee Berry Disease existed in the affected districts for at least one or two seasons before it was reported and that it was mistaken for other coffee maladies. Chief of these was dieback; a condition of the bushes produced by the death of the primaries from the tips downwards. In Kenya this is almost always due to non-parasitic agencies and differs from what is seen in Coffee Berry Disease, as all the leaves and other appendages attached to the branch die with it.

Brown blight, as described by Butler(1), in India, is widespread in Kenya but is on the whole unimportant. It usually attacks the berries in the ripe or nearly ripe stage only, and, beyond staining the bean slightly and making the pulping operation somewhat difficult, does little harm. It, however, has been confused at times with the Coffee Berry Disease. It occasionally happens that, owing to sudden ripening of the crop or other cause, it is impossible to pick the berries as fast as they ripen. If such mature coffee is left on the bushes for long, it dries up and becomes black and is then known as *buni*. This condition has also been mistaken for Coffee Berry Disease but may be distinguished from it by the fact that *buni* berries always contain fully developed beans of marketable value. Recently Thomas(2) has mentioned a disease in India, which is known as black bean or *jollu*. It causes staining, shrivelling or rotting of the coffee bean, and it is sometimes accompanied by the formation of a brown liquid. No pathogenic organism has been detected in connection with the trouble. It seems unlikely that it is in any way connected with the Kenya disease with which no wet-rot has ever been associated and no difficulty experienced in discovering a pathogenic fungus. Dr C. H. Gadd informs me that green coffee berries in Ceylon are sometimes attacked in a manner similar to that seen in Kenya. The Ceylon disease, however, has not received much attention and cultures which Dr Gadd kindly isolated for me from one such diseased berry differ markedly from those isolated in this country.

The Fungus.

Numerous cultures on carrot agar were made from diseased pulp, beans, berry stalks and portions of twigs from three different plantations in one of the districts and from one plantation in the other. The material was invariably externally sterilised in 1/1000 mercuric chloride solution before plating, but, as the specimens had to be brought nearly two hundred and fifty miles to the laboratory, a journey often taking a week, it was not surprising to find that a mixture of fungi appeared in the cultures. In more than seventy-five per cent. of the cases, however, a fungus appeared in the cultures which was white at first, became dark green later, and produced spores of the *Colletotrichum* type. Where the cultures originated from the shrivelled beans this fungus developed pure in a large proportion of them. In addition a species of *Phoma* occurred with moderate frequency, while one or two species of *Fusarium*, a *Macrosporium* and bacteria occurred so irregularly as to appear negligible as causal agents

Inoculation experiments.

Soon after the first isolations were made, a preliminary inoculation test was carried out on some green coffee berries on an experimental farm near Nairobi. Only the *Colletotrichum* cultures were used. About five per cent. of the inoculated berries developed typical symptoms and the fungus was afterwards re-isolated from them. This percentage of successful results was not considered sufficiently conclusive evidence of the cause of the disease. The bushes used, however, were particularly vigorous and were growing under very different conditions from those in the affected districts hundreds of miles away. It was decided, therefore, to carry out further inoculations in one of those districts.

For this purpose pure cultures were prepared of the *Colletotrichum* and the *Phoma* found in connection with the disease. The latter fungus was included because it did not appear so rarely in the original isolations as to justify its omission. Culture tubes of *Colletotrichum* isolated from a brown blight spot on a coffee leaf growing at Nairobi were also prepared. These were taken, in July, 1924, to an estate in the affected district and inoculations were carried out on green berries in all stages of development in two plantations approximately a mile apart.

Inoculation was effected by inserting mycelium and spores into small punctures on the berries made by the point of a sterilised needle. Only healthy branches were utilised and in each case a neighbouring branch of the same bush was used as a control and a similar number of berries was treated in exactly the same way except for the omission of the inoculum. The inoculated branches and controls were enclosed immediately after treatment in waxed paper bags, which had small pinholes on the under sides to avoid the accumulation of excess moisture within.

The brown blight *Colletotrichum* was inoculated into seventy-five berries and the *Phoma* sp. into forty-eight. At the end of six weeks all the treated berries and controls were perfectly healthy. The *Colletotrichum* which had been originally isolated from berries affected with Coffee Berry Disease was inoculated into about one hundred and fifty berries. After five days, two berries showed a small discoloured area at the inoculation puncture and typical symptoms speedily developed. Two days later, concentrically arranged acervuli were visible on the disease spots, and numerous other inoculated berries were becoming diseased. Six weeks after inoculation, seventy-two, or about forty-eight per cent., of the inoculated berries had become

typically diseased. From these the fungus was afterwards recovered in culture. All the controls remained free from disease.

Cultures made by plating short lengths of twigs bearing the dead stalks of some of the berries successfully inoculated in the above experiment developed a growth of the Coffee Berry Disease fungus only from the first few millimetres of the twigs immediately adjoining the berry stalks.

In 1925, during a later visit to one of the affected districts, the opportunity was taken of carrying out more inoculation experiments. The particular object was to explore further the possibility that more than one strain of *Colletotrichum* from coffee might be capable of producing the same symptoms on green coffee berries. The strains used were from a coffee leaf and a coffee berry respectively, both of which were attacked by brown blight. In addition, *Colletotrichum gloeosporioides* isolated from a lemon leaf was used, and, for comparative purposes, the Coffee Berry Disease *Colletotrichum* which had been obtained from the second affected district, a hundred miles away, was inoculated into some berries at the same time. The method employed was the same as that of the previous year, and the results of this series of inoculations are summarised in Table I.

Table I. *Showing results of inoculation of green coffee berries with* Colletotrichum *from various sources.*

Date	Source of *Colletotrichum* used	Number of berries treated	Diseased berries when examined on		
			29. vi. 25	7. vii. 25	14. vii. 25
19. vi. 25	Control	30	Nil	Nil	Nil
	Berry affected with Coffee Berry Disease	20	6	13	13
20. vi. 25	Control	20	Nil	Nil	Nil
	Coffee leaf	40	Nil	Nil	Nil
20. vi. 25	Control	20	Nil	Nil	Nil
	Coffee berry affected with brown blight	40	Nil	1?	2
20. vi. 25	Control	20	Nil	Nil	Nil
	Lemon leaf	40	Nil	Nil	Nil

It will be seen from the Table that, apart from the actual Coffee Berry Disease fungus, the only *Colletotrichum* which produced disease in the berries was that obtained from a berry affected with brown blight. This, as has been previously explained, is regarded by the writer as a quite distinct disease. In the case of the two diseased berries, owing to difficulties which need not be gone into, no attempt was made to re-isolate the fungus. Nevertheless, even assuming that the disease was definitely caused by the brown blight *Colletotrichum*, it will be

seen that no signs were noticed until more than double the time required by the Coffee Berry Disease fungus to produce noticeable symptoms had elapsed. This applies both to the inoculation series of 1924 and that of 1925. Furthermore, after twenty-four days the brown blight *Colletotrichum* had produced disease in only two cases out of forty, compared with thirteen successful inoculations out of twenty with the Berry Disease fungus.

The Coffee Berry Disease fungus was also introduced into needle punctures at twenty points on green coffee twigs and into the tissues of thirty-five coffee leaves of varying age. The leaves and twigs were bagged as before after inoculation. Ten and twenty controls respectively were kept in which the treatment was identical except for the omission of the inoculum. The results at the end of twenty-four days were in every case negative and hence in keeping with the observed symptoms of the disease.

It has already been stated that acervuli were frequently found on the dried pulp of berries affected with Coffee Berry Disease and that these fructifications could not be distinguished microscopically from *Colletotrichum coffeanum* Noack. As the result of work with pure cultures on several different media, certain constant differences have been observed between the fungus of Coffee Berry Disease and *Colletotrichum* from other coffee sources. In the course of this investigation, several parallel series of cultures were made of *Colletotrichum* derived from coffee leaves, twigs, berries affected with brown blight and berries affected with Berry Disease. The chief media used were coffee bean extract agar, carrot agar and coffee wood blocks. The cultures were always inoculated within a few minutes of one another and all of one series were grown simultaneously in the same incubator. The agar media cultures in such series were always from the same batch of medium and the coffee wood blocks were made from the main stem of the same coffee bush.

No two of the fungi showed identical types of growth on any of the media but the differences between the *Colletotrichum* from twigs and that from leaves were very small. Incidentally it may be mentioned that *Colletotrichum* from both these sources has at various times given rise, in cultures, to perithecia, the asci and ascospores of which agree closely in form and dimensions with *Glomerella cingulata* (Stonem.) Spauld. & v. Schr. The brown blight fungus from coffee berries did not reach a perithecial stage nor did that of the Coffee Berry Disease *Colletotrichum*, unless certain sterile sclerotia-like masses which occasionally occurred may be considered as attempts at perithecial formation. This last fungus was also characterised by the lack of formation of definite acervuli, but this character was

too inconstant in the other fungi also to be of much value. The form and dimensions of the conidia varied for all four fungi on the different media but the range of variation and the average dimensions were so much alike that they were useless as a means of differentiation.

In one particular, namely the colour of the mycelium, however, the Coffee Berry Disease *Colletotrichum* always differed markedly from the rest. These all appeared perfectly white to the naked eye throughout their growth on all media used, whereas the former fungus invariably became coloured after the first two or three days' growth. This coloration differed with the medium but was always constant with each particular medium. The change from white to colour appeared to coincide with the formation of the first conidiospores. On carrot agar the first change was to green, and, with the growth in diameter of the mycelial colony, there was a gradual enlargement of the green area from the centre outwards, always leaving a narrow periphery of white as long as active growth was taking place. With age the green darkened until eventually the culture was almost black and of a uniform tint.

The colour change on coffee wood blocks was through dark green to practically black with a white margin while active growth lasted. On coffee bean extract agar the changes were not so distinct owing to the dark colour of the medium, but various shades of grey preceded the eventual blackish colour. The Coffee Berry Disease *Colletotrichum* showed a great tendency to form dark brown chlamydospores on the drying out of the media. These were very similar in appearance to the appressoria produced on germination of the spores and were probably largely the cause of the very dark colour of the old cultures.

In connection with the above-recorded colour differences exhibited by different forms of *Colletotrichum* from the same host, it is interesting to note that Burger(3) found much the same differentiation amongst different strains of *Colletotrichum gloeosporioides* (Penz.) Sacc. He also found that spore measurements varied with the medium and that the strains were not all affected alike. During the investigation numerous measurements were made for comparison between the conidiospores of the fungus causing the Coffee Berry Disease and those of *Colletotrichum* from a coffee leaf affected with brown blight. Table II, in which the former fungus is represented by the abbreviation "CBD" and the latter by "CL," gives the measurements on three different media. Of these three media, the coffee wood not only bore noticeably longer spores in both fungi but the spores were also more profusely produced than on either of the other media.

Table II. *Measurements in microns of conidiospores of* Colletotrichum *from two different coffee sources grown on various artificial media.*

Fungus	Medium	Conidiospore measurements
CL	Coffee bean agar	12·1–18·9 × 4·4–5·9 (exceptional spores up to 22). Average 14·5 × 5·2
CBD	,, ,,	11·0–18·9 × 4·6–6·4 (exceptional spores up to 22). Average 15·2 × 5·5
CL	Coffee wood blocks	12·5–23·0 × 5·1–6·6 (exceptional spore 27·5). Average 16·5 × 5·7
CBD	,, ,,	12·8–25·3 × 5·1–6·8. Average 18·7 × 5·7
CL	Carrot agar	13·2–20·9 × 5·1–6·4. Average 15·4 × 5·7
CBD	,,	12·3–18·7 × 5·1–6·8. Average 15·6 × 5·9

Several series of hanging drop cultures were made to compare the germination stages of spores of the two fungi. The media used were two per cent. glucose solution and tap-water respectively. The chief points noted are shown in Table III.

It will be seen that in the glucose solution, where growth conditions were more favourable, slight but quite definite differences occurred. The most noticeable of these were the measurably finer hyphae of the Coffee Berry Disease *Colletotrichum* and the greater tendency of the latter to form chlamydospores, a feature already noted in connection with growth on solid media. The coffee leaf *Colletotrichum*, on the other hand, produced spores more profusely but the difference in this case was not quite so striking.

The dark brown bodies formed on the germ-tubes are here called "appressoria" and those produced on the lateral branches "chlamydospores." This distinction is made for convenience only and is not intended to indicate any real difference in character.

Since the fungus from the diseased berries has so far failed to produce a mature perithecial stage on any of the media on which it has been grown and as perithecia have not been found in the field, it is impossible to be very definite as to its exact relationship to other forms of *Colletotrichum* on coffee. The characters of the acervuli on natural infections on coffee berries, however, are so closely in accord with those of *Colletotrichum coffeanum* Noack that it seems impossible to regard the former as a distinct species. The author prefers therefore to regard it for the present as merely a strain of *Colletotrichum coffeanum* Noack. Sufficient evidence has not been collected to show that the forms of *Colletotrichum* on coffee constitute a polymorphic species such as Burger considers *Colletotrichum gloeosporioides* Penz. to be, but there are indications that such is the case.

Table III. *Comparison between the germination stages of spores of* Colletotrichum *from a coffee leaf and from a coffee berry affected with Coffee Berry Disease.*

Culture liquid	Age of culture in hours	A. *Colletotrichum* from coffee leaf	B. Coffee Berry Disease *Colletotrichum*
Sterile tap water 22° C.	21	Very few spores germinated. No appressoria. Single germ tubes	Several spores germinated, a few with two germ tubes. Occasional germ tubes with an appressorium
	43	Germination general. Appressoria uncommon. Lateral branching sparse. No chlamydospores	Germination general. Appressoria numerous. Lateral branching sparse but some branches terminated by chlamydospores
	66	Hyphae much longer than in B. Very few, scarcely pigmented chlamydospores	Chlamydospores numerous, as many as five on one mycelium. Very few spores formed
	92	Chlamydospores in moderate numbers but most of them almost colourless. Spores fairly numerous	Dark brown chlamydospores terminating practically all lateral branches. Spores few
	120	Most chlamydospores dark brown but not so numerous as in B	As at 92 hours except hyphae adjacent to chlamydospores becoming tinted brown
	138	No change	No change
Sterile 2% glucose solution 22° C.	7–15	Germination begun. Some spores septate. Germ tubes stouter than in B	Germination begun. Some spores septate
	24	Appressoria rare and indistinct	Appressoria formed where in contact with cover glass. Occasional appressorium already germinating. Elsewhere in drop as in A, except hyphae not so stout
	48	Branching vigorous, mycelium visible to naked eye. No spores yet formed. Appressoria as at 24 hours	Branching vigorous on mycelium which formed no appressoria. Visible to naked eye. Mycelium with appressoria little branched. Sparse production of spores
	72	Spores numerous, frequently more than one from same conidiophore. Moderate number of chlamydospores where in contact with cover-slip	Spores few and nearly all from lower part of drop. Chlamydospores numerous in contact with glass
	96	Growth ceasing. Total spore production much greater than in B. Hyphae 1–7 μ diameter	Growth ceasing. Chlamydospore production much greater than in A. Hyphae 1–5·5 μ diameter

Spraying with Bordeaux mixture or carbide Bordeaux mixture (an equally efficient substitute in which lime is replaced by calcium carbide when good lime is not available) has proved effective in controlling the Coffee Berry Disease. Spraying, however, is a tedious operation in large plantations, and experiments are in progress to test the value of certain manures in increasing the resistance of the bushes to the disease. It has also been observed that some types of bush show a considerable degree of immunity to the disease and seed selection work is therefore being carried out. Some years must elapse, however, before definite results can be looked for from this work.

Summary.

1. A new and destructive disease attacking green coffee berries was reported in Kenya in 1922.

2. The symptoms of the disease and the conditions under which it occurs are described.

3. Certain other conditions found in coffee which might be confused with the present malady are mentioned.

4. A fungus, whose fructifications on the affected berries cannot be distinguished from those of *Colletotrichum coffeanum* Noack, has been isolated from diseased material and has been proved by inoculation to be the causative agent.

5. Comparisons have been made between the growth in artificial culture of this fungus and that of other strains of *Colletotrichum* from coffee. The possible relationship between these is briefly discussed.

6. Methods of controlling the disease are indicated.

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ON A CORE ROT AND PREMATURE FALL OF APPLES ASSOCIATED WITH SCLEROTINIA FRUCTIGENA.

By W. J. Dowson.

(With Plate V and 1 Text-fig.)

1. Occurrence.

The present paper deals with a curious internal rotting and the premature fall of certain varieties of apples which occurred at the Royal Horticultural Society Gardens at Wisley, Surrey, in the summer of 1925. Towards the middle of July of that year it was noticed that the fruit of the trees of the early-ripening apple "White Transparent" had fallen in large numbers, and that of those remaining on the trees a few were yellower than the rest. At the time it was considered that this variety had ripened a little earlier than usual.

The largest of the fallen apples were picked up with a view to eating, but on biting into them every one was found to have a soft, rotten and brown core. Closer inspection showed that most of them were marked by a small, soft, brown patch, about half an inch in diameter, either surrounding the calyx, or at the base, about the insertion of the stalk. Some had no brown patch or other external blemish at all.

When cut in half longitudinally, every apple, whether bearing a brown patch or not, was found to be rotten at the core.

The yellower, and apparently ripe apples, still attached to the trees were in the same condition. The rot was most extensive in those with the basal marking, and least so in those without any external sign. In every fruit examined the rot involved not only the upper part of the core, but always the tissue between this and the calyx, and in those apples with a basal brown patch, the rot extended from just beneath the skin of the eye, right through the core, down to, and round the insertion of the stalk including the skin. In every specimen cut open the seeds were fully formed but were nearly all soft and rotten, the parchment chamber was discoloured brown and a fluffy white mycelium was sometimes present in the core cavity, either attached to the walls or to the seeds. In the more advanced stages of the rot a good deal of the flesh outside the core and extending to the exterior was in a similar rotten condition. The boundary separating the sound from the diseased tissue was quite sharply marked, not merely by the contrast in colour but also by a difference in consistency (see Plate V, fig. 2).

A thorough search of the orchard for any other varieties which might be similarly affected led to the discovery that the varieties "Domino," "Langley Pippin" and "Duchess of Oldenberg" also exhibited the same premature fall associated with a core rot, but to a much less degree than "White Transparent."

All the four varieties ripen early and their fruits mature during August and September; in addition they all have soft, mealy flesh.

Microscopic examination of the soft discoloured tissue taken from various parts, and from many apples revealed the presence of a copious mycelium consisting of hyphae of very variable thickness (3μ–19μ). In a few specimens bacteria were also present in addition to the mycelium.

2. Production of *Monilia* Type of Conidia on the Diseased Apples.

On July 15th a number of fallen apples of "White Transparent" and "Domino," some with and some without the brown external patches were gathered from the orchard and all except ten cut open. These ten were placed in a box and kept in the dark, the rest were kept on the laboratory bench in the light.

On August 15th some of the cut-open apples had turned completely brown and had produced pustules of what appeared to be *Sclerotinia* (*Monilia*) *fructigena*. Such apples were removed and placed in a separate box. As time went on more and more of the cut apples turned brown and bore pustules of spores identical in appearance with those of the brown rot fungus.

The ten apples kept in the dark did not form pustules and after a month were much shrivelled in appearance, brown nearly all over except for a few greenish areas of irregular shape, and soft to the touch. A few of them were placed outside in the open, partly buried in sand contained in a flower pot; the remainder were kept in the dark and at the time of writing are completely mummified, grey in colour and without any pustules.

3. Isolation of the Mycelium.

Two plates of Brown's agar(1) were inoculated with pieces of the soft discoloured tissue taken with sterilised forceps from two freshly collected apples which had been cut open for the purpose with a flamed knife. The plates were inoculated on August 12th, and on the 14th, with the aid of a lens, colourless hyphae could be distinguished growing out from all the pieces of diseased apple. By August 17th fairly large growths measuring one inch in diameter had been produced. One of the plates

was then uncovered and examined under the microscope when the presence of both conidia and microconidia was observed. The latter, in considerable quantity, were arranged in parallel chains arising from a single conidiophore and presented the appearance of a *Penicillium* under the low power of the microscope.

Far less numerous were the conidia, also arranged in single or branched chains. These were of the *Monilia* type and corresponded in size with those of *Sclerotinia* (*Monilia*) *fructigena*.

Careful examination showed that the microconidia were produced, one at a time, from the tip of a short conidiophore, and their appearance agreed with that of the genus *Sclerotinia*. Nowhere, and at no time, on these particular isolation plates did the characteristic pustules of *Sclerotinia* (*Monilia*) *fructigena* develop. From these plates subcultures were obtained on steamed potato plugs in tubes, which did eventually produce yellow pustular growths of the *Monilia* type observed by Wormald(2).

Cultures of undoubted *Sclerotinia* (*Monilia*) *fructigena*, obtained from ripe fruit in the same orchard, when grown on this medium were almost identical in appearance with the above; as were also the cultures from the *Monilia*-like pustules which developed on the cut-open diseased apples. On the three sets of cultures pustular patches, buff in colour, were formed on the upper surface of the potato plugs which were otherwise covered with a fluffy white mycelium.

4. Inoculation Experiments.

The presence of the soft brown discoloration either at the stalk or at the eye end of the fruit, together with the thick septate hyphae in the rotted tissue, which when isolated produced the conidial forms of the brown rot fungus, suggested that this indeed might be the cause of the disease, either alone, or in company with other organisms.

Accordingly, it was decided to find out what the effect would be when sound apples were inoculated with the three strains of *Sclerotinia* (*Monilia*) *fructigena* already mentioned.

A large number of inoculations were made during August using apples of many different varieties, some quite small and immature, but the majority were normal apples taken from trees which ripened their fruit somewhat later than the four affected varieties. The results were so uniform that it is not necessary to give them all in detail.

The inocula used were (1) conidia of *Sclerotinia* (*Monilia*) *fructigena*, (2) the similar conidia produced on cut-open diseased apples mentioned above, (3) small pieces of the rotted tissue,

(4) mycelium taken from pure cultures of *Sclerotinia* (*Monilia*) *fructigena*, and (5) mycelium taken from pure cultures of the isolated fungus. The apples were inoculated either (*a*) beneath a small triangular flap of skin, or (*b*) on to the core by means of a hole drilled right through the apple with a cork borer, or (*c*) beneath a conical piece cut from the eye and afterwards replaced, or (*d*) by means of a needle-stab down through the eye and varying in depth from an eighth to half an inch.

With the exceptions of (*b*) and (*d*), the result of inoculation was uniformly the same however performed. The first sign of infection occurred from two to three days after inoculation when a brown discoloration appeared at the place where the inoculum had been introduced. On the following day one or more pustules of the *Monilia* type made their appearance and in the course of a few days the whole apple became soft, brown and covered with pustules.

With method (*b*) the process took a little longer, three to four days for the appearance of browning and four to five for the production of the first pustule. In (*d*) the method of introducing the inoculum (conidia in this instance) was regarded as approaching as nearly as possible that which might actually have happened in nature: hence the inoculations under this heading may be given in detail.

Inoculation No. 10 *made on August 27th,* 1925.

Six apples were chosen and pierced through the bottom of the calyx depression as near to the centre as possible by plunging a hot needle down to a distance of about half an inch. A drop of sterilised water containing a suspension of conidia derived from an apple previously inoculated with *Sclerotinia* (*Monilia*) *fructigena*, was placed, by means of a pipette, in the calyx cavity of five of the apples; the sixth received water only and served as a control. The apples were placed on the laboratory bench and covered with a bell-jar.

On August 31st a drop of distilled water was added to the eyes of the six apples but no sign of infection was then evident.

On September 2nd, *i.e.* six days after inoculation, three of the apples bore an irregularly shaped brown patch surrounding the calyx, and all five inoculated apples were found to be soft about this region when pressed with the finger. On the same date all the five were cut open and carefully examined. The tissues extending from the calyx to the base of the core in a vertical direction and past the core in a horizontal direction were soft and discoloured brown. The vascular bundles were more deeply stained brown and were noticeable beyond the discoloured flesh, suggesting that the hyphae had travelled

along the bundles in advance of the mycelium in the rest of the tissue. One marked difference between the rot so produced and that of the naturally infected apples was the diffused edge of the rot in the former as contrasted with the much more sharply delimited margin in the latter. Otherwise, in this experiment the rot produced was closely similar to that observed in nature. The sixth (control) apple remained sound.

Inoculation No. 11 *made on September 3rd,* 1925.

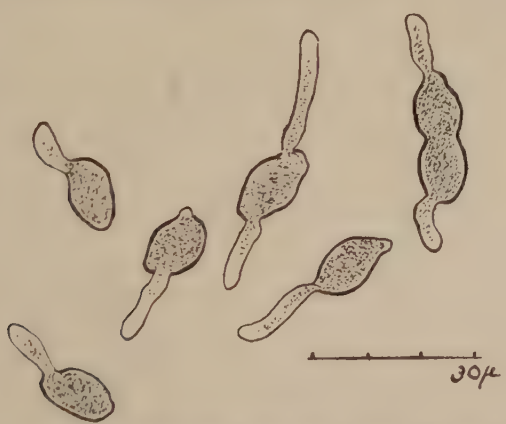
This was a repetition of No. 10 with the exception that instead of making a stab half an inch long, the skin at the bottom of the eye was just pierced and no more. Subsequent examination showed that the greatest depth to which the hot needle had sunk was an eighth of an inch. The inoculum in this experiment was a suspension of conidia taken from a pustule which had formed on one of the cut-open diseased apples kept in the laboratory.

On September 15th one of the five apples bore a large brown patch round the calyx and had begun to produce pustules: none of the others showed signs of infection and when cut open no trace of such could be found.

In a similar experiment in which no wound at all was made, the inoculation drops being placed in the unwounded eyes, no infection resulted.

5. Germination of the Conidia.

Two observations of interest were made with reference to the germination of the conidia. By means of a series of hanging-drops of various media, the germination of the conidia of the



Text-fig. 1. Conidia of *Sclerotinia fructigena* two and a half hours after sowing in a hanging-drop of Brown's agar.

fungus isolated from the rotted apple tissues, was compared with that of *Sclerotinia* (*Monilia*) *fructigena*. No difference between the two could be detected. On drops of Brown's agar and in tap water containing apple juice, the conidia of both strains began to germinate in the surprisingly short time of sixty to ninety minutes, but no germination was observed to occur in distilled water or tap water alone. The presence of organic substances seems to be necessary for the production of germ tubes although this point has not yet been investigated in detail. Germ tubes were produced from any part of the conidium (see Text-fig. 1).

6. Results of the Foregoing Observations and Discussion.

That the mycelium contained in the soft and discoloured tissues of diseased apples belongs to *Sclerotinia* (*Monilia*) *fructigena* follows fairly clearly from the observations and inoculation experiments described above. As to whether this fungus was the sole cause of the rot, or, whether other organisms, *e.g.* bacteria, were also involved, the evidence so far to hand is not conclusive. In none of the inoculations was a rot produced exactly like that observed in naturally infected apples in which the advancing edge of the rot was more sharply marked than in the artificial inoculations.

This may have been due to the means of entry of the fungus in the first instance, and also to the condition (immaturity) of the infected tissues. So far, there is no definite evidence as to when and how infection occurred; though the fact that in every specimen examined the upper portion was infected right up to and often including the skin of the eye, indicates the probability that the fungus had gained entrance at this end.

The apples may have been infected at an early stage of development, possibly even during the flowering period when the blossoms may have been visited by insects bearing spores of the fungus. This however implies the presence of conidia at an unusual season of the year, and yet it does not seem likely that the fungus had been introduced in any other way than by spores.

It is just possible that infection may have arisen from ascospores from old mummies. The apothecial form of *Sclerotinia fructigena* has been known on the continent since 1905(3) but has not yet been recorded for this country.

Experiments have been planned, with the object of obtaining more information as to how, when and where *Sclerotinia fructigena* gains entrance to apples, so as to produce an internal rot.

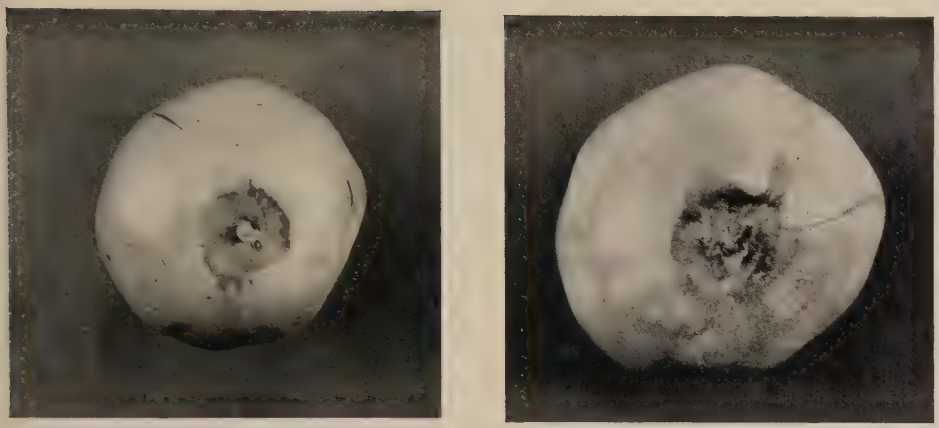


Fig. 1.

Fig. 2.

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EXPLANATION OF PLATE V.

Fig. 1. Core rot of apple "White Transparent." On left, view of stalk end showing soft brown patch. On right, view of eye end showing soft brown patch.
Fig. 2. Top. Views of the same two apples as seen when cut in half. Bottom. An apple without any mark upon the outside as seen when cut in half. Note the rotten tissue between the base of the calyx depression and the core in all three. The only mark on No. 1 (top left) was that shown in Fig. 1 (left), the *skin* of the apple appeared quite sound, but the tissue just beneath was rotten.

SUCCESSIONAL DISEASE IN PLANTS AS SHOWN IN WILLOW RODS.

By N. L. Alcock, F.L.S.

(With 1 Text-fig.)

The course of disease in plants, in the light of recent investigations bears a striking resemblance to that of the micro-organisms whose attacks upon the human body are rarely successful when the latter possesses normal powers of resistance. We are apt to forget how close is the resemblance between the two forms of life, animal and vegetable.

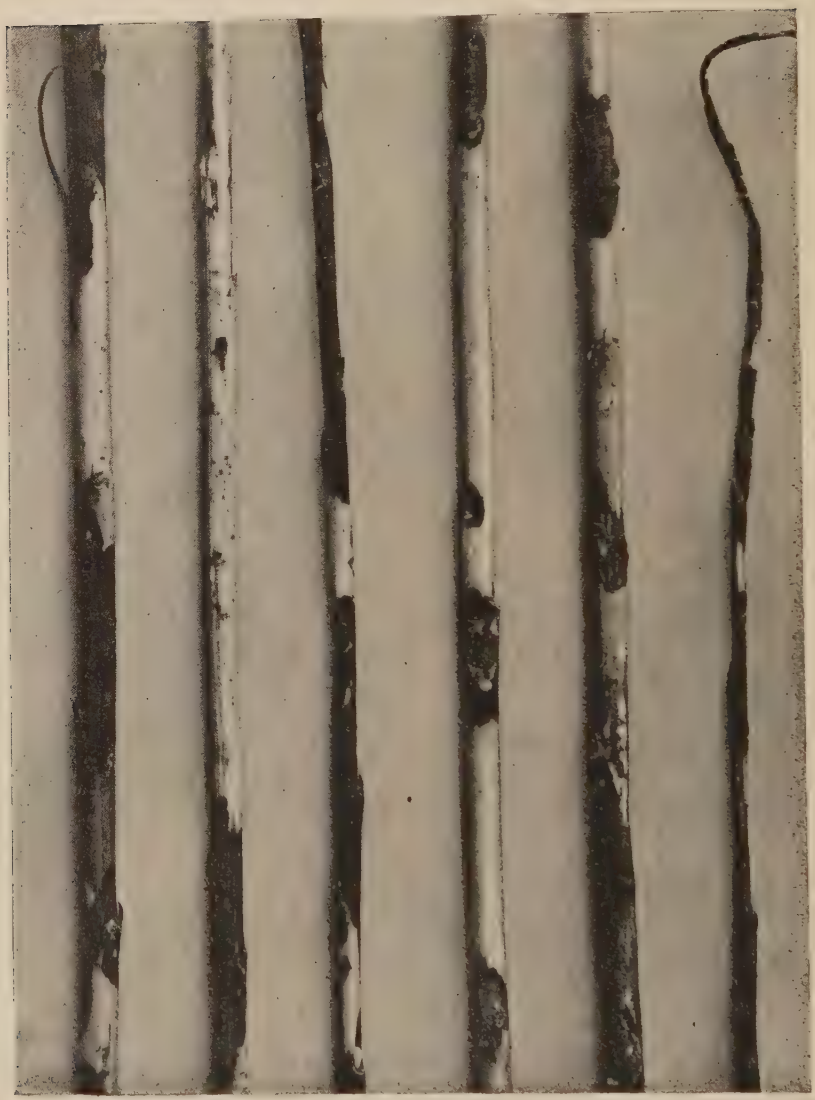
Resistance to disease in both cases fails for three main reasons: (*a*) an unsuitable environment, mismanagement or injury, (*b*) neglected attacks of minor ailments, (*c*) and only occasionally by the attack of a specific disease of remarkable virulence. This finds a good illustration in the four diseases here described.

(1) The Willow Scab, actively parasitic like apple scab, attacking willow rods and much assisted by faulty methods of cutting.

(2) The three diseases in succession on the crack willow, which show how one disease leads to another and how the weakened plant ceases to have its full power of resistance.

The Willow Scab, *Fusicladium saliciperdum* Tubeuf, is a strong parasite, the most actively parasitic perhaps of the four.

The second, *Cryptomyces maximus* (Fries) Rehm, is also a parasite, *Scleroderris fuliginosa* (Pers.) Karst. a semi-parasite, *Myxosporium scutellatum* (Otth.) Petrak hardly a parasite, mostly



Fusicladium saliciperdum Tub. on willow rods.

a saprophyte, but all were injuring the trees on which they were found.

Willow Scab (*Fusicladium saliciperdum* (All. & Tub.) Tubeuf) (8, 9, 10). This disease was noted on willow rods by a market gardener in Lanark and the specimens sent to the Botanic Garden, Edinburgh. They were suffering from killed and curled tips, striking black blotches on the stem, giving a piebald appearance, and in some cases an extensive die-back.

Although osiers are little grown in Scotland, the growers and nurserymen frequently grow a few willows and cut them over for their own use. There is no reason that I know why willows, which grow particularly well in Scotland, should not be grown commercially.

These rods were apparently *Salix alba* var. *vitellina*. A parasitic fungus was present and after examination it was decided that the disease was that known on the Continent as Bark Scorch of Willows, a troublesome disease of willow rods grown for culture.

Fusicladium saliciperdum (All. & Tub.) Tub. is very closely related to the fungus causing apple scab, *Fusicladium dendriticum* Fckl. (*Venturia inaequalis* Aderh.). The perfect stage of *Fusicladium saliciperdum* is said to be *Venturia chlorospora* (Ces.) Karst. This form, as far as I know, has not been seen in Great Britain. The disease attacks many species of willows, including *Salix alba*, *S. aurita*, *S. caprea*, *S. cinerea*, *S. cuspidata*, *S. fragilis*, *S. mollissima*, according to Rehm (3, 776); also *S. nigricans* and *S. pentandra* according to Tubeuf (11). It has been noted in Bavaria and other parts of Germany, in Denmark, and recently in the Netherlands (12), where it has caused a disease, particularly of the weeping willow. The ordinary weeping willow in the Netherlands is *Salix vitellina* var. *pendula*—not *Salix babylonica*, as in the British Isles.

The disease appears first as dark blotches on the leaves, covered with a velvety pile, the dark olive-coloured area sharply contrasting with the green of the healthy leaf. These spots resemble the spots on the apple leaf caused by apple scab, and are similarly covered with the fungus producing its conidial fruiting stage. The upstanding conidiophores, bearing at the apex the conidial spore, give the velvety appearance to the diseased area. The spore is large, varying in size from $15 \times 5\mu$ to $22 \times 10\mu$, but usually about $18 \times 6\mu$. When first formed this spore frequently appears non-septate, but when mature is typically 1-septate with a constriction at the septum, hence the statement frequently made that the spore is shaped like the sole of a shoe. The spores are exceedingly variable in size and shape. These early spots on the leaf give rise to further infection in several ways:

(1) The spores are carried to and infect another leaf.

(2) The spores are carried or blown to the tender tips of the young shoots, and, infecting the soft tissue, cause a die-back; the shoot turning black, the tip sometimes curling in a hook as in *Monilia* tip-wilt of plum.

(3) The parasite spreads over the leaf and travels along the mid-rib and down the petiole to the leaf-base and infects the cortex of the stem at the junction of the leaf, spreading above and below. The withered mid-rib may be seen on several diseased twigs still attached by the withered petiole to the stem.

The infection by the fungus causes the bark to turn black, and the disease thus forms striking long-shaped patches on the bark. The black discoloration is sharply marked out on the yellow bark of the rod, and an infected twig looks strongly piebald. In a bad case the infected areas run together until the whole rod is black.

On these black areas small pustules are formed under and pushing up the epidermis. They are often roughly set in an oval, a half circle being found some way above the point of infection, and a half circle some way below—others are scattered. They are of varying size but many are from one-fourth to one-third of a millimetre. These pustules are formed of a compact mass of fungal tissue which can go through a dormant period in a similar manner to the behaviour of the resting-stage of the cushion of apple scab. It is probably in these cushions that the fungus over-winters. When the conditions are favourable the mass of hyphae grows and forces up and finally ruptures the bark. At first the pustule has a shiny black appearance, but when the cushion has burst through the bark, it becomes covered with spores and short conidiophores, and appears dusty and dark olive-brown.

These spores act again as a source of infection, and judging by the similarity of the form on the willow twig to the dormant stage of apple scab on such apples as Cox's "Orange Pippin" this is the origin of the early infection on the leaves of the willow.

In dealing with the other bark troubles of willow, such as *Physalospora gregaria* Sacc., often called willow canker, which is common in Somerset on basket willows (*S. triandra*, *S. viminalis*, etc.), it has been found that the disease is very much increased by the habit of cutting the rod of the required length only. In other districts where the custom has been to cut right out down to the stool and trim the rod afterwards, the disease has been much less troublesome. In dealing with osier willows, or stools of willows kept for commercial or useful purposes in nurseries, the rod should be cut as low down and as near to

the stool as possible. Any long stub left forms a home for the pustule form of this scab. Long stubs should therefore be avoided.

All diseased twigs should be cut out so far as possible during the winter and burnt before the dormant pustules awaken and form spores. If the value of the willow or the usefulness of the withies will warrant the expenditure of money and labour, a winter wash of copper sulphate—four pounds of copper sulphate to one hundred gallons of water—could be given in the winter, or lime sulphur—one gallon to twenty-nine gallons of water—might be tried in the spring. In the case of osiers, spraying the stumps with Bordeaux mixture after cutting might be tried.

The three other diseases were acting in succession on the crack willow (*Salix fragilis*).

Cryptomyces maximus (Fr.) Rehm (1,246; 2,707; 3,107; 4; 5), the first of these, is a distinct parasite. This fungus forms long black cushions on the green or yellow-green bark of the willow twig. The cushion may be six or eight inches long, raised above the bark, with a curious blistered appearance at the edge of the cushion, the black colour of which contrasts strongly with the pale tint of the willow shoot. The top of the long cushion is flat and silvery black. At a little distance the infected branches look as if they had been scorched with fire. The fungus is parasitic on living twigs of various willows, which it sometimes entirely girdles. It seems that the apothecial cushions burst through the young green bark in the late summer or autumn, maturing in spring. The hymenium takes up about a third of the whole thickness of the cushion. It is of an olivaceous black on the outside and of a dark colour within. The lower part of the substance is white. The asci are very long with eight spores. The spores are oval, obtuse, one-celled, with a central oil drop, colourless or slightly yellowish, 20–26μ × 10–18μ. Paraphyses are present and abundant, appearing like brownish threads among the asci and very long. Rain causes the black cushions to swell and scale off, leaving long scars in the bark. The disease generally spreads over branches, even to the small twigs, frequently causing the death of the twig above the infection.

Scleroderris fuliginosa (Pers.) Karst. (1,250; 2,595; 3,210; 6), the second disease, is very destructive in action when it has found a means of entry in a weakened host. In this case it had entered *via* the scars and lesions made by the *Cryptomyces*. Other diseases, such as the Yellow Rusts, *Melampsora* spp. also form a means of entry for further fungus trouble on the willow.

Dr Malcolm Wilson, for whose help in this work I am much indebted, gives an interesting case where a series of fires had been made in the forest in the disposal of slash. These fires had been too near to some Douglas Firs, which are, in any case,

particularly susceptible to scorching. Up each tree was a narrow strip of scorched bark, and each scorched area was covered with the fructifications of *Scleroderris livida*, a fungus very like the one on the willow. The circle round where the fire had been was distinctly marked by the trees bearing the fungus.

Scleroderris fuliginosa occurred round the edges of the flat cushion, formed by *Cryptomyces maximus*, as a collection of large brown or black pycnidia. On other branches, weakened by the *Cryptomyces*, this fungus has appeared above the first disease.

The pycnidia are very large, up to a quarter of a millimetre, often with a flat top, in some cases almost square, opening by a pore at the top. They grow closely huddled together. They have rather the appearance of turnip or rape seed set round and encroaching over the black flat cushions of the *Cryptomyces*. The spores contained within the pycnidia are hyaline, 20–30μ long, with three or four divisions. They are borne on short conidiophores, set all round the inside of the pycnidium. These conidiophores remain with the appearance of a fringe when the spores are washed out. Following these pycnidial fructifications an apothecial stage occurs, forming in and occasionally on the top of the pycnidial stage.

These apothecia are at first squatly round, and closed at the top with a dent in the summit, often with a stout stem-like base. The disc is greyish white, about a quarter to three-quarter mm. across, but varying in size, the exterior brownish black. The asci are very long and club-shaped, with the needle-shaped spores arranged in a parallel bundle within the sac. The ascospores are very long, up to 60μ, hyaline, pointed at both ends, thin, mostly straight, with seven or eight divisions. Slender colourless paraphyses are present. This fungus is provisionally identified as *Scleroderris fuliginosa* (Pers.) Karst.

Myxosporium scutellatum (Otth.) Petrak(7). After the young shoots of *Salix fragilis* had been considerably weakened by *Cryptomyces maximus* and *Sclcroderris fuliginosa*, *Myxosporium scutellatum* appeared on the dead and injured twigs practically as a saprophyte but increasing the areas of injury. These dead areas may be a foot or more in length in which case the tree may be greatly disfigured and useless for many purposes. The fungus is perennial, living from year to year in the bark and causing a fresh diseased area each year. Scattered over the dead bark are innumerable disc-shaped areas about the size of a pin's head. These represent the fructifications of the fungus, and are at first under the epidermis. Later the epidermis ruptures, and the fructifications appear as cup-shaped or saucer-like structures. The bark in many cases tends to peel off readily, carrying the fructifications with it.

In transverse sections the fructifications consisted of a single chamber, though in a few cases the columnar structure was visible in the centre, indicating a division into two compartments.

Dr Petrak, who kindly assisted in the identification, has now placed his fungus in a new genus—*Cryptosporiopsis*.

I am indebted to the kindness of Mr J. Fraser, of the Forest School, Beauly, for these specimens of *Salix fragilis*.

It is hoped to carry out inoculation experiments this year and the willows are being grown in the Royal Botanic Garden.

The succession of diseases on the crack willow, *Salix fragilis*, dealt with here, illustrates clearly how one disease can lead to another, and how a plant in a weakened condition ceases to have the full power of resistance.

Diseases may be caused by such virulent parasites that the healthiest of plants will succumb. But a good many fungus diseases depend on lack of vigour in the host. A plant lessened in strength by a strong parasite will frequently become the victim of many half-parasitic fungi. A plant grown in bad conditions, overcrowded, or on an unsuitable site, will suffer from fungal trouble where a tree on suitable soil, at a right elevation, will probably never have a disease unless the virulent specific parasite appears. For example, the White Pine Blister Rust, or the Chestnut Bark Canker, that has destroyed the chestnut forests of the Eastern United States, will attack the most flourishing tree in the best condition and site.

Again, plants are more susceptible to disease at certain times. Seedlings are at a critical stage in their career and will readily succumb to fungus attack under unfavourable conditions. Such operations as transplanting or grafting form times of danger to the plant, when for the moment its resistance is low and enemies have a chance. But one of the commonest dangers is that one fungus, possibly not very serious in itself, may form a means of entry for another which will do great harm.

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REVIEWS.

The Romance of the Fungus World. By R. T. and F. W. ROLFE. Chapman and Hall, Ltd. xiii + 309 pp. 12*s.* 6*d.* net.

Under the above alluring title two of our members, Messrs R. T. and F. W. Rolfe, have gathered together in one volume miscellaneous information of a kind that should attract readers outside the charmed but very restricted circle of mycologists.

These, too, will find the book worth having, especially if they are in search of the padding that is indispensable in a popular lecture. After all, one cannot expect an audience to be "thrilled" over the subtle differences of species, but the dreadful lethal habits of Amanita this, and the less deadly but intoxicating ways of Amanita that, have a perennial interest. Such information is supplied abundantly in this book. There are chapters on fungi in Folk-lore, Literature, Medicine, Industry, etc. The photographs are very good; they are mostly by Mr A. E. Peck, and he must be delighted to see them so well reproduced. Mr Ramsbottom bestows his blessing in a short Foreword.

A. A. P.

A Text-Book of Organic Chemistry, Historical, Structural and Economic. By JOHN READ. G. Bell and Sons. xii + 680 pp. 12*s.* 6*d.* net.

Mycologists and botanists in general have frequent occasion to refer to books on Organic Chemistry. The new book on this subject by Professor J. Read is probably the most suitable for workers in biology that has yet been published, for the author has devoted special attention to the substances such as alcohols, sugars, starches, celluloses, essential oils, etc., which play so important a part in plant metabolism and which are of such great importance economically. Frequent reference is made in the book to the bio-chemical activities of micro-organisms. Apart from its intrinsic merit to students of biology the book is written in an extraordinarily interesting manner and contains a fascinating account from the historical standpoint of the rise and development of the study of Organic Chemistry.

F. T. B.

PROCEEDINGS.

AUTUMN FORAY AND ANNUAL MEETING, DUBLIN. *21st—26th September.*

AUTUMN FORAY FOR LONDON STUDENTS, OXSHOTT. *10th October.*

FORAY WITH ESSEX FIELD CLUB, EPPING FOREST. *17th October.*

FORAY WITH BRITISH ECOLOGICAL SOCIETY, BURNHAM BEECHES. *24th October.*

MEETING. UNIVERSITY COLLEGE, LONDON. *21st November.*

S. DICKINSON. A new method of isolating single spores.

W. J. DOWSON. Fall of apples associated with a core-rot due to *Sclerotinia fructigena.*

J. RAMSBOTTOM. Fragmenta mycologica. IV.

ALEX. SMITH. *Penicillium* diseases of *Gladiolus* and *Narcissus.*

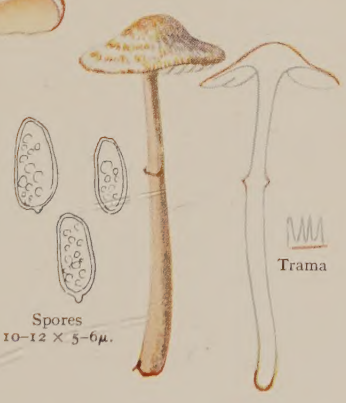
A. L. SMITH. Lichen Dyes.

W. BUDDIN and E. M. WAKEFIELD. Life history of a fungus parasitic on *Antirrhinum majus.*

Lepiota pratensis (Fr.) Rea.

Lepiota echinella Quél. & Bern.

Lepiota castanea Quél.



Lepiota gracilis (Quél.) Rea.

E. A. & V. Rea del.